Hello my ASHRAE friends. As we continue through our seemingly endless winter, I must confess I am quite proud of the support our members and friends continue to give our great chapter even through winter weather advisories! I recently joined the ASHRAE Bowling League, and absolutely love seeing so many different faces every week at the alley. I have been spreading the word to let everyone there know their proceeds go to fund our amazing scholarships we give to Engineering students each year.

Speaking of fundraising, I must congratulate everyone who helped make the Nebraska ASHRAE Dodge Ball Tournament a huge success! Our sponsorship was phenomenal and so was the turn out! People came with winning attitudes, no matter the score, and generous hearts! Collectively we raised around $4,000! A big thanks to Eric Holtmeyer for all the time and effort he put into planning the event; yes he had lots of help, but when Digz called the night before and mentioned the little detail of not having any balls for our event the next morning, Eric was the one who ran around town and haggled down the price for literally dozens of balls!

It’s because of all of our amazing and active members we are able to host the cities longest standing bowling league, and the coolest Dodge Ball tournament in all of ASHRAE. Thank you to all who help in any way to make our chapter strong.

If you are looking to get involved in one of the awesome events we host through Nebraska ASHRAE reach out to me, and I’ll help you find the right place in our group. I will also make sure anyone who emails me about getting involved before March’s lunch meeting gets lunch free.

Stay warm!

Sincerely,

Sarah Poursharafeddin, MBA, LEED-AP
Nebraska ASHRAE Chapter President 2013-2014

FYI
ASHRAE Indoor Air Quality Guide is now available for free download, see the link below.

https://www.ashrae.org/resources-publications/bookstore/indoor-air-quality-guide
Omaha Meeting – Tuesday, March 11th, 2014

- **Location:** Anthony’s Steakhouse, 7220 F Street, Omaha, NE 68127
- **Check-in:** 11:30 a.m. (Please arrive early to facilitate serving meals)
- **Lunch:** To be served prior to 12:00 p.m.
- **Menu:**
  - Club Sirloin $21.00
  - Chicken Cordon Bleu $16.00
  - Grilled Salmon $16.00
- **Topic:** “Thinking Like an Engineer”
- **Speaker:** Victor W. Goldschmidt, PhD, Professor Emeritus, Purdue University, School of Mechanical Engineering

Pre-registration for this meeting would be GREATLY APPRECIATED!!!

Reservation required by Monday, Mar 10th, 2014: Nick Mandel, Specialized Engineering
nmandel@specializedeng.com

Omaha Featured Speaker

Victor W. Goldschmidt, Emeritus Mechanical Engineering Professor, served at Purdue University from 1964 through 2000. He is currently serving as a Leelanau Township Trustee and Planning Commissioner as well as a facilitator and engineering consultant.

During his 36 years at Purdue University, Mr. Goldschmidt was responsible for educating mechanical engineering students, including the direction of graduate research in the HVAC area. Most of his service with graduate students was with the Ray W. Herrick Laboratories with heavy support from the HVAC industries. During early stages of his career, he served as Director of the Engineering Purdue Fellows in Latin America; during later stages he served as department head for Freshman Engineering. Prior to his academic involvement, he worked in Applications Engineering and Development Engineering with Honeywell.

Mr. Goldschmidt has taught almost every course in thermal sciences offered at Purdue, as well as a special upper level technical course on the “Creative Process in Engineering.” He is trained as a Synectics (special brainstorming) facilitator and is currently engaged in the development of strategic plans and problem solving sessions.

A past ASHRAE Director-at-Large, he also has served as a member of Publishing and Technology Councils. He is an ASHRAE Distinguished Service Award recipient and Fellow, as well as Honorary Member of IIR, ACAIRE, ASURVAC and AAF. He resides in North Michigan, above Traverse City.

Future Omaha Chapter Meetings

- **Apr. 8th**
  - UNO Student Chapter Meeting
- **May 14th**
  - Haymarket DEC/Arena Tour Joint with Omaha, LES
- **June 16th**
  - ASHRAE Golf Outing

11:45 @ Anthony’s
TBD
Iron Horse
Lincoln Meeting – Wednesday, March 12th, 2014

Location: Valentino’s, 70th & Van Dorn, Lincoln
Check-in: Noon (Please arrive early to facilitate serving meals)
Lunch: To be served prior to 12:00 p.m.
Menu: Buffet $13.00
Topic: “Thinking Like an Engineer”
Speaker: Victor W. Goldschmidt, PhD, Professor Emeritus, Purdue University, School of Mechanical Engineering

Pre-registration for this meeting would be GREATLY APPRECIATED!!

Reservation required by Tuesday Mar 11th, 2014: Mike Barry, Black Hills Corp
mike.barry@blackhills corp.com

Lincoln Featured Speaker

Victor W. Goldschmidt, Emeritus Mechanical Engineering Professor, served at Purdue University from 1964 through 2000. He is currently serving as a Leelanau Township Trustee and Planning Commissioner as well as a facilitator and engineering consultant.

During his 36 years at Purdue University, Mr. Goldschmidt was responsible for educating mechanical engineering students, including the direction of graduate research in the HVAC area. Most of his service with graduate students was with the Ray W. Herrick Laboratories with heavy support from the HVAC industries. During early stages of his career, he served as Director of the Engineering Purdue Fellows in Latin America; during later stages he served as department head for Freshman Engineering. Prior to his academic involvement, he worked in Applications Engineering and Development Engineering with Honeywell.

Mr. Goldschmidt has taught almost every course in thermal sciences offered at Purdue, as well as a special upper level technical course on the “Creative Process in Engineering.” He is trained as a Synectics (special brainstorming) facilitator and is currently engaged in the development of strategic plans and problem solving sessions.

A past ASHRAE Director-at-Large, he also has served as a member of Publishing and Technology Councils. He is an ASHRAE Distinguished Service Award recipient and Fellow, as well as Honorary Member of IIR, ACAIRE, ASURVAC and AAF. He resides in North Michigan, above Traverse City.

Future Lincoln Chapter Meetings

Apr. 9th
UNL Controls, Stefan Newbold
Noon @ Valentino’s

May 14th
Haymarket DEC/Arena Tour Joint with Omaha, LES
TBD

June 16th
ASHRAE Golf Outing
Iron Horse
**Student Activities Message**

Attention ASHRAE Members! Please let us know all the ways you are working with students to help promote engineering. Examples of your volunteer efforts or educational assistance we are looking for include:

- How many student involved activities, mentorships, lectures have you as an ASHRAE Member completed with post high school students.
- How many student involved activities have you as an ASHRAE Member completed or participated in with students in the K-12 age range? Please let us know the student age and activity or event.
- How many student involved activities have you as an ASHRAE Member completed or participated in to specifically promote engineering to girls in the K-12 age range?
- Have you met with other organizations/societies to discuss joint K-12 STEM activities? Let us know what societies and activities were discussed.
- Are you a YEA member that is mentoring a student group or team?
- How many ASHRAE Student Members are currently interning at your place of employment?

This is the time to brag about all the great things our Nebraska Chapter Members do to support local students! Let us know how you are supporting students by emailing our Student Activities Chair, Kim Cowman, at krcowman@leoadaly.com.
The ASHRAE Technology Awards recognize outstanding achievements by members who have successfully applied innovative building designs, which incorporate ASHRAE standards for effective energy management and indoor air quality. Only six projects received first-place ASHRAE Technology Awards that were presented at the 2014 Winter Conference in New York City. The Nebraska Chapter’s very own Darren Dageforde was awarded ASHRAE Societies 1st Place award in the new residential category for his home in Blair. Darren and his wife Karen built their new residence over the course of about 2-1/2 years. They started contemplating the project, conceptualizing the house and looking for the right location back in late 2008. Darren worked on the design process in his spare time throughout 2009. Construction began in May 2010 and they moved in May 17, 2011.

The Dagefordes sought to create an extremely energy efficient home with minimal maintenance, low utility costs and at a reasonable budget. The resulting design was an air conditioner-less (no traditional air conditioner/furnace), walkout raised ranch home operating at an energy use density of a remarkable 5.24 kBTU/ft2-yr.

The house design is an adaptation of traditional high performance commercial and residential systems incorporating some state of the art technologies and original design concepts. The skeleton of the structure consists of insulated concrete form walls and concrete floors with a standard truss rafter system. A small solar array of 4.1KW of photovoltaic panels is installed on the roof. Environmental conditioning is provided by hydronic radiant heated and cooled floor slabs. The radiant system utilizes a large mass of the insulated concrete flooring deck system as a thermal storage mass to evenly and continuously distribute thermal energy to the occupied environment. The radiant heating system is driven from water-to-water heat pump connected to five closed loop geothermal wells as the heat source. An original application geothermal tempered fresh air supply system provides humidity and carbon dioxide control for the home. Domestic hot water is generated by a water-to-water heat pump also served from the geothermal well system. Through system integration “reject cooling” is recaptured from the domestic hot water heat pump for partially cooling the home in the summer time. Any required additional cooling is derived directly from the geothermal well system. During the summer of 2012, the hottest summer on record in Nebraska, a total of 93 kWhrs was measured at an actual direct energy cost of $3.70 to cool and air condition the house for the entire summer, a reduction of over 95 percent from an average regional house, not including the energy benefit of site generated energy. The slightly milder summer of 2013 required a mere 90 kWhrs for home cooling.

Though greatly more efficient than a typical house, this home was constructed at a cost significantly less than market price for a comparable custom home thus demonstrating the Dageforde’s goal that incredible energy efficiency does not have to be expensive!

The entire 10-page project summary is attached.

Darren Dageforde is the Director of Utilities for the University of Nebraska Medical Center in Omaha, Nebraska. He earned his bachelor’s degree in Mechanical Engineering from The University of Nebraska – Lincoln and is a registered Professional Mechanical Engineer in Nebraska. At UNMC he responsible for the central generation and distribution of chilled water, steam, emergency and normal power.
PROFESSIONAL DEVELOPMENT COURSE

Hydronic Balancing

HOSTED BY ASME DISTRICT C – NEBRASKA SECTION

Wednesday, March 19, 2014
8:00 a.m. – 4:30 p.m.
Mahoney State Park Lodge
Ashland, NE

Earn Eight Continuing Education Hours

Join your colleagues for this course on hydronic balancing. A hydronic machine transmits heating or cooling power. Prioritization in design, system effectiveness, controllability, maintainability, and operational energy consumption are components to a successful system. This presentation offers tools to read and analyze hydronic systems, covers hydronic system architectures, and defines controllability and ways to increase it.

Our instructor will be Hooman Daneshmand, P.E. Hooman is a Hydronic Trainer for TA Hydronics, a manufacturer of hydronic balancing valves, control valves, and water quality equipment. He has 7 years of valve development, design, production, supply chain, and application experience in Oil & Gas, hydronic, beverage dispense, and pneumatic applications. He received his Bachelors of Science in Mechanical Engineering from UCLA with a focus on heat transfer and control systems.

The course fee is $110 for ASME members and $135 for non-members. There is a discounted fee of $75 for retirees and students. This fee includes course materials, CEH certificate, daily park pass, continental breakfast, lunch, and refreshments. Breakfast will be available starting at 7:30 a.m., and the course begins at 8:00.

Profits are used to fund scholarships and support student activities in both high school and college such as Power Drive, SAE Mini Baja, Create Robotics Competition, and student engineering chapters.

Paid reservations are required and are due by March 14.

Contact Jay Fluehr at FluehrEngineering@gmail.com for more information.

Register and pay online via credit card using “Register” in the link below.
If you are registering several individuals at once, please enter their names in the "Add special instructions to merchant" box on the payment review page.


If paying by check, make payment to ASME – Nebraska Section.
Send to Dave Stransky, 6638 S. 110th St., Omaha, NE 68137

• Articles for next month are due by Monday, March 31st, 2014
• Please send to: Nick Decker ndecker@olssonassociates.com
Dageforde Residence Project Summary

Project Description

The vision of this project was to create an extremely energy efficient home with minimal maintenance and low utility costs at a reasonable budget. Non-traditional commercial and industrial systems and construction methodologies would be utilized if technically and economically reasonable. It had to look, feel, and function like a traditional residential home. The goal was to become “net zero”; however, unreasonable financial commitments simply to achieve this goal would be avoided. The resulting design was an “A/C-less” (no traditional air conditioner/furnace), walkout raised ranch home design (2,160 gsf upper floor) operating at an energy use density of less than 13.2 kBTU/ft²-yr.

The skeleton of the structure consists of insulated concrete form walls and concrete floors with a standard truss rafter system. Environmental conditioning is provided by hydronic radiant heated and cooled floor slabs. The radiant system utilizes a large mass of the insulated concrete flooring deck system (>110,000 lbs of concrete for the upper floor) to store and evenly, continuously distribute thermal energy to the occupied environment. The floor is topped with ceramic tile to reduce any insulating effects of the flooring, thus minimizing the required temperature differential between the floor and the living environment. A geothermal tempered fresh air supply system provides humidity and carbon dioxide control. The radiant heating system is driven from a two speed, five ton water-to-water heat pump (operating only as a 2.5 ton unit) connected to five 200 ft deep closed loop geothermal wells as the heat source. Domestic hot water is generated by a 3 ton, two speed water-to-water heat pump (operating only as a 1.5 ton unit) also served from the geothermal well system. The basic radiant cooling design was
originally conceived as direct circulation of closed loop geothermal well water through
the radiant floor system but was improved through system integration to capture “reject
cooling” from the domestic hot water heat pump. 4.1KW of photovoltaic panels are
installed on the roof. During the summer of 2012, the hottest summer on record in
Nebraska, a total of 93kWhrs was measured at an actual direct energy cost of $3.70 to
cool and air condition the house for the entire summer, a reduction of over 95% from an
average regional house, not including the energy benefit of site generated energy.
Though greatly more efficient than a typical house, this home was constructed at a cost
significantly less than market price for a comparable home.

**Design Description**

The basic home is a 36' x 60' rectangular floorplate, open floor, raised ranch with 9'
ceiling height and a full walkout basement. Half of the basement is semi-finished living
space and half is a four-stall (small-standard car) garage and work area. 13 standard
fiberglass frame, U-.29 low E glass windows comprise 11% of the exposed wall area.
The walls are insulated concrete form (R-22, code minimum=R-19) and a flat ceiling (R-
48 attic insulation, code minimum=R-39). The upper floor is a “pan and joint” reinforced
cement monolithic pour insulated concrete form system (R-26) comprised of a 4” slab,
with radiant tubing, over 6” wide by 10” deep joists, 24” center to center. The basement
floor is a 4” concrete slab on grade with radiant tubing over R-10 insulation.

Home heating is provided by circulating warm water through the radiant floor tubing cast
into the large mass concrete floor. Utilizing the continuous and even heat flow of the
large mass floor system covered with low energy resistance ceramic tile, the floor
temperature is typically in the 72˚-76˚F range, requiring a supply water temperature in
the 76˚-80˚F range for heating. This supply temperature is ideally suited for heat pumps, especially geothermally coupled systems. This water-to-water geothermally coupled system is approximately 40% more efficient than traditional water-to-air geothermally coupled systems which require around 110˚F supply air temperatures. Due to the non-traditional requirements of the control system and the need to automatically gather large volumes of data, a small programmable logic computer controls all of the mechanical systems. Several large, low-E windows face south. The roof eave overhang is specifically designed to provide full window shading in the summer and full sun in the winter. During the heating season, the passive solar gain raises the living area temperature up to 4.5˚F above normal with much of the thermal energy absorbed by the dark-colored tile into the floor mass. This thermal surge will carry elevated temperatures until very late in the evening without any supplemental heating from the heat pump system.

Initially, cooling was to be provided by direct circulation of cool geothermal well water through the radiant floor system, a very efficient and cost-effective means of cooling. As the design evolved, other modes of even more efficient heat rejection were incorporated. With the exception of dedicated drinking water, in the cooling season all domestic cold water (40-70˚F) from the local municipal water supply is routed via dedicated PEX tubing through the floor slab to extract “free cooling” by increasing the water temperature up to near 74˚F, the temperature of the floor. Next, heat is recovered from the mass floor via swapping valves on the geothermal system. This change allows the domestic hot water heat pump to bypass the geothermal system and take heat directly from the home via the radiant floor and deliver the heat to the domestic hot
water. Since the floor operates up to 20°F above the well temperatures, this design is over 30% more efficient than direct geothermal coupling for the domestic hot water system and it provides almost “free cooling” to the house. Because the large mass of the floor system acts as a thermal storage tank, the typical energy recovery timing problems due to generation not coinciding with load usage are eliminated. Thus, using domestic hot water provides home cooling that will be stored until it is needed. Finally, if any additional cooling is needed, the control system will circulate cool water from the geothermal wells directly through the radiant slab.

Domestic hot water is generated via a geothermally coupled water to water heat pump, preheated via independent tubing in the upper floor structure. In the summer, this design provides free cooling for the home and free preheat for the water. In the winter, the radiant floor heat pump, due to much lower lift requirements, operates at least twice as efficiently as the domestic water heat pump. Preheating domestic water with the radiant heat pump system results in significantly reduced total energy consumption for domestic hot water heating as compared to a single heat pump for water heating.

As the basic house structure was constructed to be very tight with low infiltration, interior air quality becomes a major concern. ASHRAE 62.2-2007 Design Guidelines for
Residential Construction requires fresh air make-up via energy recovery ventilation systems. Carbon dioxide and humidity control to this home is provided via a geothermally conditioned fresh air supply system instead of energy recovery ventilation. Outside fresh air is drawn underground through a 160' long, 8” diameter, 22 gauge steel duct (PVC coated for corrosion resistance) that is sloped toward the house. In the summer, approximately 100 cfm of hot, humid air is drawn into the duct and cooled/dehumidified to 60°F (saturated) via a small Energy Star rated fan. Condensation is trapped and drained at the house entrance. The air is pulled through a MERV 8 filter and delivered to the occupied space while the bathroom exhaust fan is operated to exhaust air from the space. In the summer this system actually provides the first stage of home cooling. Similarly, in the winter, 45-60°F air is supplied for environmental contamination control as well as preheating the outside air to minimize the load on the heating system. Due to instrumentation response lag, running the system on a periodic timer (approximately 200 minutes spaced throughout the day) provides better indoor air quality control with improved energy efficiency than a CO₂ concentration control (demand control) strategy.

18 photovoltaic solar panels on the roof generate 4.1kW of grid-connected site power electricity. The system size is based on payback from current utility rates. These panels provide enough energy to supply the heating, cooling, and domestic hot water heating needs of the home or over 60% of the total energy consumed. Due to the extremely low energy consumption of the equipment required to cool the home, nearly all of the energy produced in the summertime is exported to the utility grid during the peak daytime hours. Most of the energy in the home is consumed by evening lighting
and morning water heating for bathing, laundry and cooking. This design reduces the utility peak demand and increases the load during non-peak time, a win-win situation for both the utility company and the homeowner.

**Energy Efficiency**

<table>
<thead>
<tr>
<th>2012 Annual Total Energy Consumption of Dageforde Home</th>
<th>Does not include solar panel impact</th>
<th>Actual kWhrs</th>
<th>Regional Average* kWhrs</th>
<th>%</th>
<th>Kansas/Nebraska average house** kWhrs</th>
<th>%</th>
<th>Energy Density*** kBtu/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling</td>
<td>93</td>
<td>967</td>
<td>10%</td>
<td>1348</td>
<td>7%</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Home heating</td>
<td>4461</td>
<td>20457</td>
<td>22%</td>
<td>16471</td>
<td>27%</td>
<td>5.21</td>
<td></td>
</tr>
<tr>
<td>Water heating</td>
<td>2104</td>
<td>7278</td>
<td>29%</td>
<td>6594</td>
<td>32%</td>
<td>2.46</td>
<td></td>
</tr>
<tr>
<td>Ventilation</td>
<td>146</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Other living uses</td>
<td>4451</td>
<td>9379</td>
<td>47%</td>
<td>7825</td>
<td>57%</td>
<td>5.20</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11255</td>
<td>38081</td>
<td>30%</td>
<td>32239</td>
<td>35%</td>
<td>13.15</td>
<td></td>
</tr>
</tbody>
</table>

*Regional average based on 2009 US IEA Residential Consumption survey for average Midwest home, 2500-3000 ft², 3 household members, gas heat and gas water heater.

**Average houses in Nebraska and Kansas are much smaller than regional averages and utilize gas heat and gas water heating.

***An attempt was made to model the home in Trane Trace and other software. The resulting data was unreasonable and could not be validated. Thus modeling data was omitted.

The actual recorded energy required to cool the home during the summer of 2012, the hottest summer on record in Nebraska, was 93 kwhrs, a reduction of 90% energy as compared to average houses of equivalent size, not corrected for actual weather, which was 148% of average cooling degree days. Heating energy was 22% of a comparable average home. (Actual heating degree days were 79% of normal.) Actual domestic hot water heating energy requirements were reduced to 18% of the owner’s previous home (gas water heater) or 29% of a regional average home (gas heater).
Indoor Air Quality

This design provides excellent indoor air quality without sacrificing energy efficiency. Residential construction code ASHRAE 62.2 does not address fresh air requirements, thus commercial and industrial ASHRAE62.1 code was used as the design guideline. Carbon dioxide levels as measured within the living space very, very seldom exceed 1200 ppm and are routinely maintained less than 1000 ppm. The calendar year 2012 averaged 778 ppm CO$_2$. Given the region’s atmospheric CO$_2$ levels average around 350 ppm and that ASHRAE research references 700 ppm above atmospheric as typically acceptable criteria (350+700=1050 ppm), the data indicates that the house is, on average, adequately to nearly over-ventilated. With no carpeting, there are very few places to trap allergens and there is very little dust or particulate debris being transported and deposited anywhere in the home from a traditional air handling system.

Ultimately, indoor air quality is a relative term measured by the satisfaction of the occupants. The three occupants of the house all agree that the indoor air quality is outstanding. With radiant cooling systems, a space temperature setpoint of 75˚F borders on too cold in the summertime and would be comparable to an air cooled system thermostat setting 3-5˚F cooler. Relative humidity levels are maintained within the 30-65% comfort range specified in standard 62.1. In the winter, relative humidity averages 41% without supplemental humidification. In the summer, 65% and lower relative humidity is nearly always recorded. Humidity control deviations were generally related to very large groups/tours and occupants opening windows. The large thermal mass of the floor provides outstanding temperature control and stability with rapid recovery. Recorded temperatures indicate that room temperatures very seldom exceed
1.5° negative deviation from the thermostat setting in both the summer and winter. Positive deviations in the winter can be as high as 5°F warmer due to uncontrolled passive heating and 1.5°F cooler in the summer during nighttime no-load conditions.

**Innovation**

Using only existing technologies, this project created a cost-effective cooling system that can cool a residence through 105°F heat and 78°F wet bulb humidity days without use of a refrigerant compression cycle. This is an innovation that has the potential to change an industry. Direct geothermal tempering and humidity control via fresh air supply is a cutting-edge design that borders on experimental in nature. Separating the dehumidification and cooling aspects of the typical air conditioning process allows a very innovative and energy effective means of temperature control through the use of radiant cooling. Developing and demonstrating an energy storage and delivery system that allows very low temperature differentials while utilizing cooler heating media and warmer cooling media has far reaching potential in improving energy efficiency. Thermal mass storage at the point of energy utilization combined with hydronic radiant distribution is an innovative combination of technologies that is rarely, if ever, seen in residential applications. This combination provides outstanding environmental temperature stability, nearly eliminating peak loads, which significantly reduces equipment sizing while increasing load factors.

Radiant cooling has only very recently started to be incorporated in high-end commercial “green” designs and was nearly impossible to find when this project was developed. Capturing free cooling via radiant cooling from the domestic water stream while simultaneously pre-heating the domestic hot water system is an entirely original
and innovative design. The core innovation in this project is the direct recovery of both energy streams of a heat pump system for domestic water heating and home cooling. By utilizing the radiant system and its thermal storage capabilities directly as the heat source for the domestic hot water heat pump, the efficiency of the domestic water heat pump is increased 33% while the total pumping energy cost is reduced for the cooling of the floor system, a win-win situation for both systems.

**Operation and Maintenance**

Required maintenance is minimal for this house. The “oversized” fresh air filter should be replaced once a year and the intake air screen checked to be sure nothing has accumulated on it. In the late spring the system is swapped from “cooling” to “heating” mode by changing thermostat switches and manually shifting five valves. In the fall, the system is switched back to heating mode by reversing the steps. It should be noted that all heating/cooling mode switching could be executed at the thermostat by simply automating five valves; however, by direction of the owner, this action has not been taken. This system has achieved the goal of minimal long-term maintenance. No condensing coil to wash and comb out, no cooling coil to clean, and no dirty return ductwork to collect dust and dirt.

**Cost Effectiveness**

Utilizing a nationally accepted industry standard reference for square foot cost estimating for various levels of construction quality, the actual cost of constructions was 21% less than an “average custom built home” in the area of comparable size. Actual cost was 2% higher than an average “package plan” house constructed from a simple design standard plan builder. It should also be noted that the actual final costs included
the PV solar panels and geothermal wells, which were not included in the estimates. However, the actual costs are also not corrected for self-performed work including construction management, mechanical system installation, and final trim and finish work. Correcting the cost estimates for these issues results in an actual cost that would be about 16% below the cost of an “average custom house” of similar size or 7% above the cost of a “package plan” home. As the cost of this home, including all the premium features, was less than the cost of a standard custom home, all paybacks were immediate.

**Environmental Impact**

This home demonstrates a 76% reduced carbon footprint as compared to an average Midwestern home. As over 67% of the summer PV electricity is exported to the utility, this house has added very little load to the utility base summer peak profile and probably has actually reduced the utility peak by 3.5 kW by the on-site PV generation.

<table>
<thead>
<tr>
<th>Year 2012 Energy Production, Consumption, Cost &amp; CO&lt;sub&gt;2&lt;/sub&gt; Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchases and production</td>
</tr>
<tr>
<td>Total KWH Produced PV's</td>
</tr>
<tr>
<td>Total KWH Purchased Utility</td>
</tr>
<tr>
<td>Total Electric Usage</td>
</tr>
<tr>
<td>Total Connection Charge</td>
</tr>
<tr>
<td>Total Energy Charge</td>
</tr>
<tr>
<td>Total Electrical Cost</td>
</tr>
<tr>
<td>Actual electricity purchased</td>
</tr>
</tbody>
</table>

The residential market consumes 22% of the energy in the U.S. and buildings in general consume nearly 48% of the annual energy used in the U.S. Adaptation and application of this design philosophy has the potential to substantially change an enormous
segment of the U.S. building industry. In summary, the house design and performance have greatly exceeded the initial goals of extreme efficiency, excellent cost effectiveness, minimal maintenance and a healthy living environment.