

Zero Energy Home Project

Team Wicked Prophets

Baker Albassam, Ahmed, Andrew Jackson, Zach Main

Pennsylvania State University

College of Engineering

EDSGN 100, Spring 2014

Bevin Etienne

Content:

- Introduction
- Mission Statement
- Abstract
- Customer Requirements
- Customer Needs
- Location Details
- Research on Zero Energy Homes
- Examples of Zero Energy Homes
- Project Specifications
- Benchmarking
- Additional External Research
- Concept Screening
- Final Project Specifications
- Final Design and Floor Plan
- Conclusion
- Sources

Introduction

Throughout the course of history, the human population has grown at an exponential rate that sees no mitigation in the near future. The United Nations predicts that the world population will reach 10 billion by the year 2065. With this severe exponential growth in human population comes an increasingly inevitable environmental responsibility among today's generation. An ecological footprint, according to the Center for Sustainable Economy, measures the sustainability of a person or group of people in terms of the amount of land it would require to support their lifestyle. In today's day and age, it is becoming necessary to support a lifestyle that limits environmental impact and maximizes sustainability. In order to have an ecological footprint of one, which would maximize sustainability, a person or family would need to produce as much energy as they consume. This is the idea behind a Zero Energy Home. While simple, the idea of a Zero Energy Home (ZEH) requires state of the art technology and modern architectural designs, as well as energy efficiency among its appliances.

Mission Statement

The Pennsylvania State University is renowned for its College of Engineering and the world class research that its students and professors undergo. In order to contribute to this success and to the needs of today's society, our team set out with the goal of creating a sustainable home that has net zero energy and costs less than \$160,000. We strive to use the design process to create an aesthetically appealing zero energy house that fits the requirements provided to us by our clients.

Abstract

The team named, The Wicked Prophets, was presented with the challenge of building a net-zero energy home. There were several requirements that the house needed to include. After evaluating the numerous requirements of the house, we began the design process. We first brainstormed many ideas for the house including what types of energy we would try to use. Then we began to create a customer needs chart to decide on what design factors of the house would receive the most attention. The next step in our design process was to research existing zero energy homes. After external research, we reevaluated our design specifications to be comparable to existing zero energy homes. Through lots of brainstorming, researching and benchmarking, the team was able to design an optimal house powered by solar energy with a net-zero energy output.

Customer Requirements

- The house must be located in Pennsylvania
- The house must accommodate a family of four
- The total cost must be under \$160,0000
- The house have net zero energy
- The house must accommodate a child with asthma

Customer Needs Analysis

Customer's Statement	Needs Statement
The house needs to accommodate a family of 4 with two young children.	The home will have 2 bedrooms, 1.5 bathrooms, laundry & mechanical room, a kitchen and living space.
One child is asthmatic and the house must be built to prevent any asthma attacks.	The house will be located away from air-polluted areas and be built air-tight.
The house must produce all of the energy the family uses in order to keep costs low.	Solar panels will produce energy for the house and the house will be located in a desirable climate.
The house must be aesthetically appealing to the surrounding area/environment.	The home will be built in Pennsylvania in a semi-rural town where neighboring houses are similar in size.

ZEH Location Details

Hummelstown, PA

Dauphin County

ZIP 17036

Demographics:

- Population as of 2012: 4,523
 - Male: 2,186 (48.3%)
 - Female: 2,337 (51.7%)
- Median household income (2011): \$56,529
 - Pennsylvania median household income (2011): \$50,228
- Median resident age: 39 years
- Estimated median house value (2011): \$170,623
 - Median house value in PA (2011): \$164,800
- 93.1% White, 3.0% Hispanic, 1.4% Asian, 1.1% African American

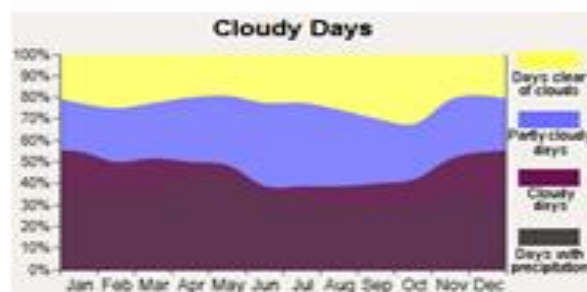
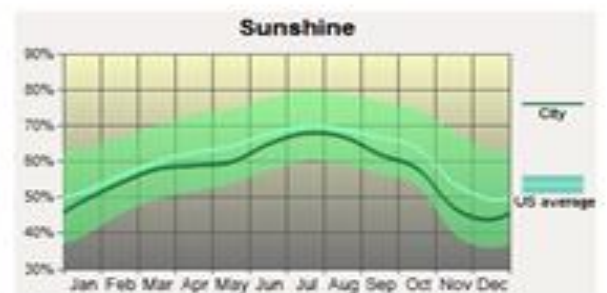
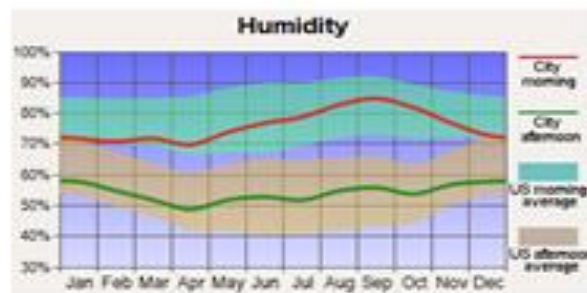
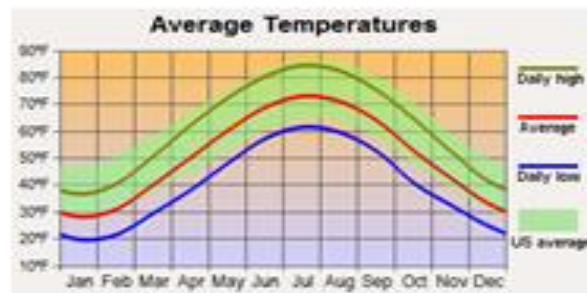
Climate:

- Latitude and Longitude: 40.236682 N, -76.687356 W
- Elevation 400 ft.

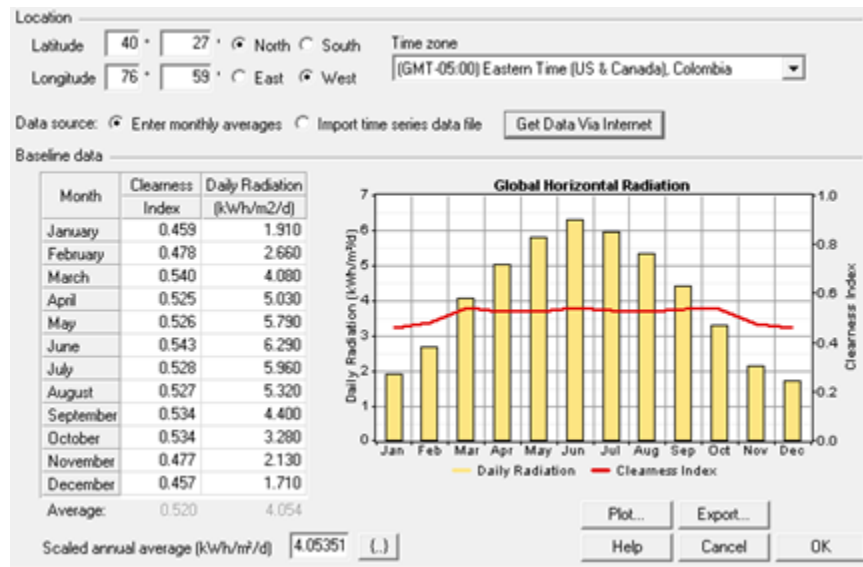
- Air Quality Index(as of March 5th, 2014): 58 (moderate-good)

Average climate in Hummelstown, Pennsylvania

Based on data reported by over 4,000 weather stations

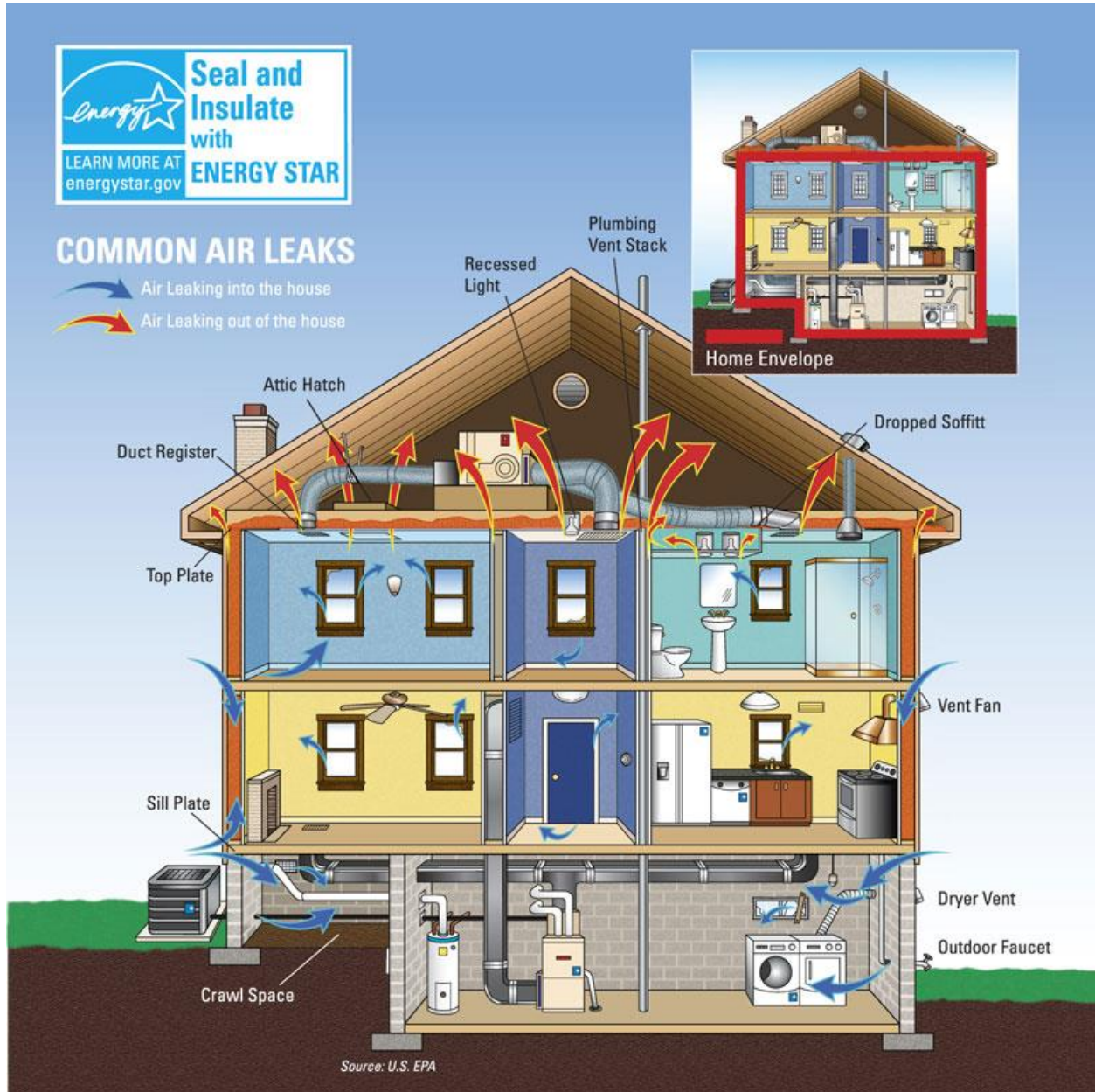


<http://www.city-data.com/city/Hummelstown-Pennsylvania.html>



- This latitude and longitude provides the maximum amount of sunlight in Pennsylvania along with a below average cost of living index. This graph was obtained using the HOMER Legacy computer program.

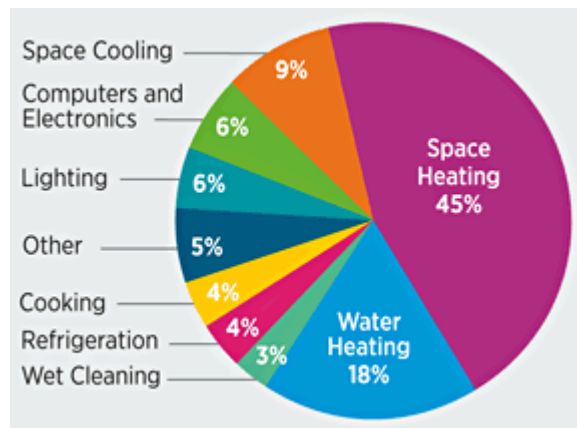
Zero Energy Home Research



- This diagram gave the team an idea of how and where heat will enter and escape the house
- After reviewing this diagram, we had a better idea of how to insulate the house and where insulation would be needed the most

Energy Saving Strategies

While the home is described as net zero energy, the term “zero energy” comes with a few caveats. If the residents do not practice sustainable living, they will be more likely to use more energy than the home can produce. Below is a list of sustainable living practices that will minimize energy usage for the residents of the ZEH. These recommendations are from the Iowa Energy Center, as well as our own calculations and observations.



Points to consider in the ZEH:

1) Air leaks

As it is shown in the pie chart, ceiling, walls, and floors play a big role in air leaking. In order to solve this problem we will use silicone or Latex to block the leaks.

2) Heating and cooling system:

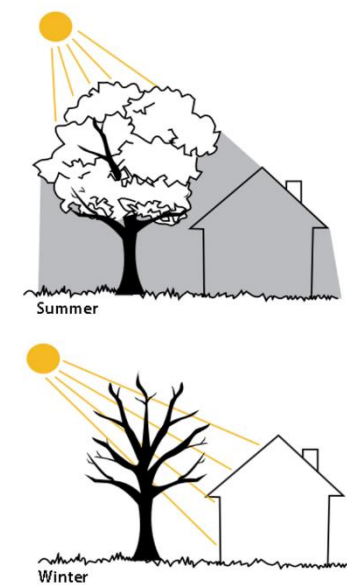
As it shown in the pie, heating almost uses half of the energy that is provided to the house. So, to reduce usage of electricity from heat as much as possible we decided to implement to following strategies:

1- Install programmable thermostat and set it as shown in the chart.

	Wake 70°	Leave 60°	Return 70°	Sleep 62°
Mon	6:00a	7:30a	5:30p	10:00p
Tue	6:00a	7:30a	5:30p	10:00p
Wed	6:00a	7:30a	5:30p	10:00p
Thu	6:00a	7:30a	5:30p	10:00p
Fri	6:00a	7:30a	5:30p	11:00p
Sat	8:00a	9:00a	6:00p	11:00p
Sun	8:00a	9:30a	1:30p	10:00p

2- Use large windows in all rooms so that the sunlight can get into the house in the winter.

3- Plant trees around the house which gives benefits both in the summer and in the winter beside its benefits to the environment.



3) Water heating:

Water heating uses about 18% of the total energy consumption, so it is useful to find techniques that can reduce energy usage in heating. There are some points to consider when we buy a heater:

- 1-use CFC-free tank the rated R-24.
- 2- Use heat tapes so that we can prevent heat losing.
- 3- Use cold water cycle while washing clothes.

4) Major house appliances:

Ideas to reduce energy usage in home major appliances:

- 1- Don't overload the dishwasher.
- 2- Use microwave instead of oven when possible.
- 3- Clean the dryer's vent regularly.

Example Zero Energy Homes

ZEH Example 1-



- 63 Green Valley Road, Williamsburg, KY
- Builder: Kentucky Highlands Investment Corporation
- 1,094 sq. ft.
- Exterior walls, and floor-
 - Insulated with blown in high density fiberglass
- Roof-
 - Attic insulated with loose fill cellulose to 18"
 - Service cavity insulated with blown in high density fiberglass
- Ecological Design
 - Net-Zero energy site with 3.75 kW grid intertie photovoltaic system

ZEH Example 2-



- Builder- PDX Living LLC
- Portland, OR
- 1,175 sq. ft.
- Exterior walls and roof
 - Insulated with blown in high density fiberglass
- Window glazing-
 - Low SHGC on North, East and West elevations
 - High SHGC on South elevation
- Entrance door: Therma-Tru
- Energy requirement
 - 36.3 kBTU/(sq.ft. yr.)

ZEH Example 3-



- Builder- Cardinal Homes
- Wylliesburg, VA
- 1,361 sq. ft.
- Exterior walls and Roof-
 - 10" SIP panels (all seams taped)
- Floor-
 - 12" TJI with Densepack Cellulose
- Ecological Design
 - Prefabricated, modular construction
 - Locally sourced materials as much as possible
 - LEED certification
- Other:
 - Architecture planning by University of Virginia, ecoMOD South Project Team

Benchmarking

New Town Builders

Denver, CO

Introducing the Solaris II Collection at Conservatory Green

Inspired by the land, the new Conservatory Green neighborhood is where you'll find New Town's all-new, energy-efficient new urban designs.

- **Net Zero Energy Option Available on All Homes**
- **From the Low \$400's**
- **3 to 5 Bedrooms ~ 2½ to 3½ Baths**
- **10' Ceilings throughout First Floor**
- **2nd Floor Laundry on Most Plans**
- **4 Floor Plans ~ 1,837 to 2,241 sq. ft.**
- **2 to 2½ Car Attached Garage**
- **Full Basement w/ 9' Ceilings ~ Option to Finish**

New Town Builders is Denver's leader in the design and construction of energy efficient homes and was the winner of Green Builder Magazine's coveted 'Green Home of the Year' for a production builder. New Town Builders also won the Homebuilder's Association's MAME Award for 'Green Home of the Year'. Both awards recognized New Town's Zero Energy home in Stapleton. New Town builds high performance homes engineered for unmatched energy-efficiency, cost savings and comfort.

Our homes perform at a higher level because we've designed a tighter home seal that protects your home, and we've taken extra steps to insulate it from the inside out, which keeps costs down, energy in, and preserves the quality of your home's indoor air. Then we enhance our homes even further by adding solar electric power. The unprecedented Zero Energy Option will be available on every Solaris II home.

All New Town homes surpass the highest required levels of energy-efficiency, but the zero energy homes have taken New Town's energy efficiency to a new level. When measured against homes built to code, New Town homes provide increased energy efficiencies that translate to a lower ongoing cost of ownership.

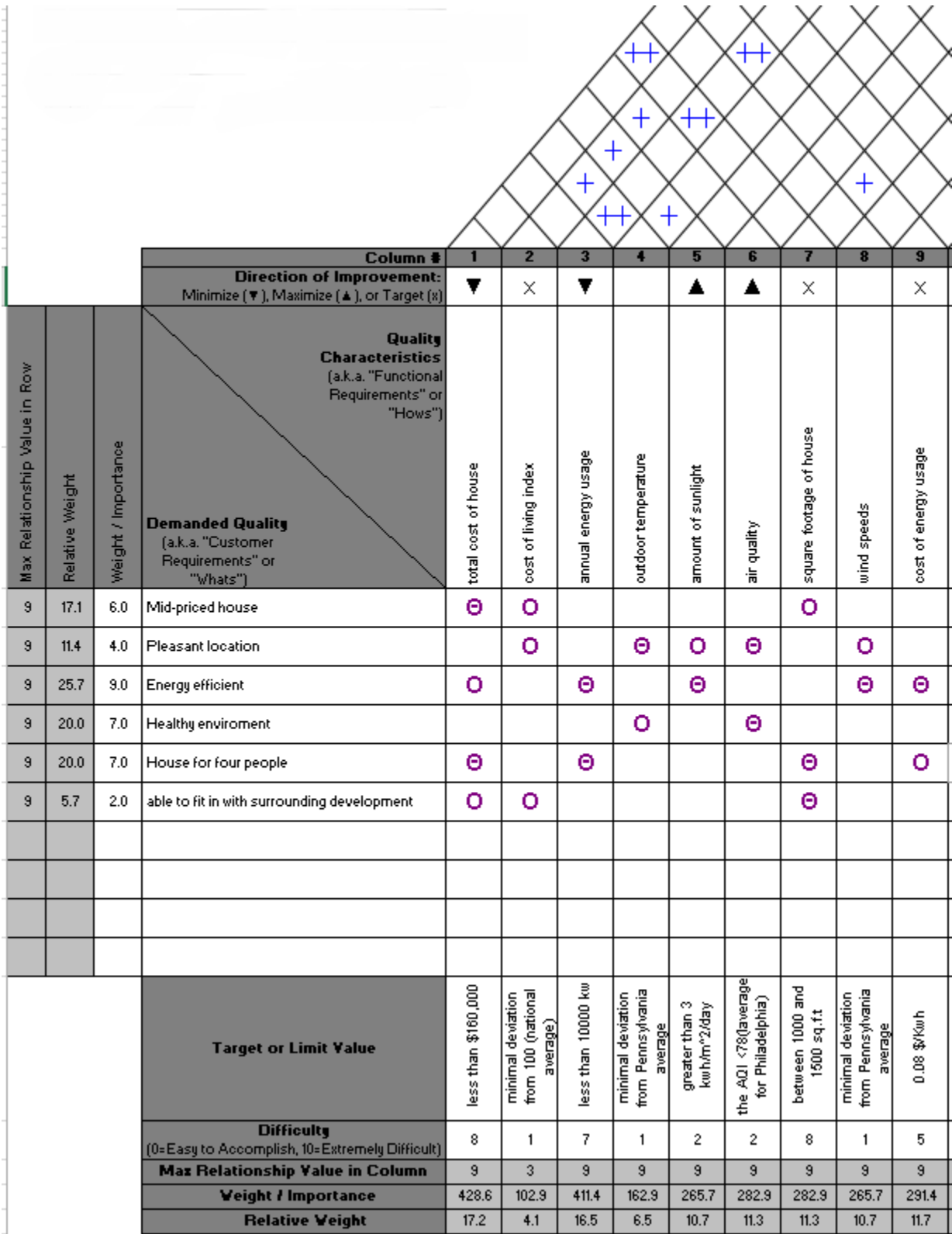
<http://www.newtownbuilders.com/>

The Process of Benchmarking

Organizations that benchmark, adapt the process to best fit their own needs and culture. Although number of steps in the process may vary from organization to organization, the following six steps contain the core techniques:



House of quality-



Concept Generation

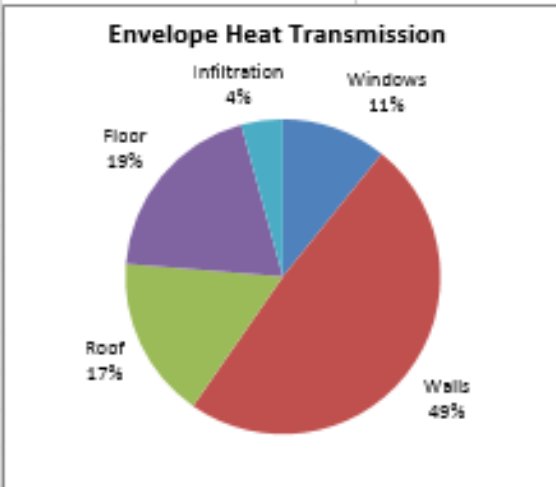
Challenges

Assumptions	<ul style="list-style-type: none">• The ZEH will have net zero energy• The ZEH will cost less than \$160,000• The ZEH will be located in Pennsylvania
Customer Needs	<ul style="list-style-type: none">• The ZEH will accommodate a family of four• The ZEH will accommodate for an asthmatic child• The ZEH will fit in with the surrounding environment
Target Specifications	<ul style="list-style-type: none">• A total cost of less than \$160,000• A total sq. footage of between 1000 and 1500 sq.ft.• An AQI of less than 78 A location the provides more than 3 kwh/m²/day of sunlight• A location that does not deviate more than 10 from the national average cost of living index of 100

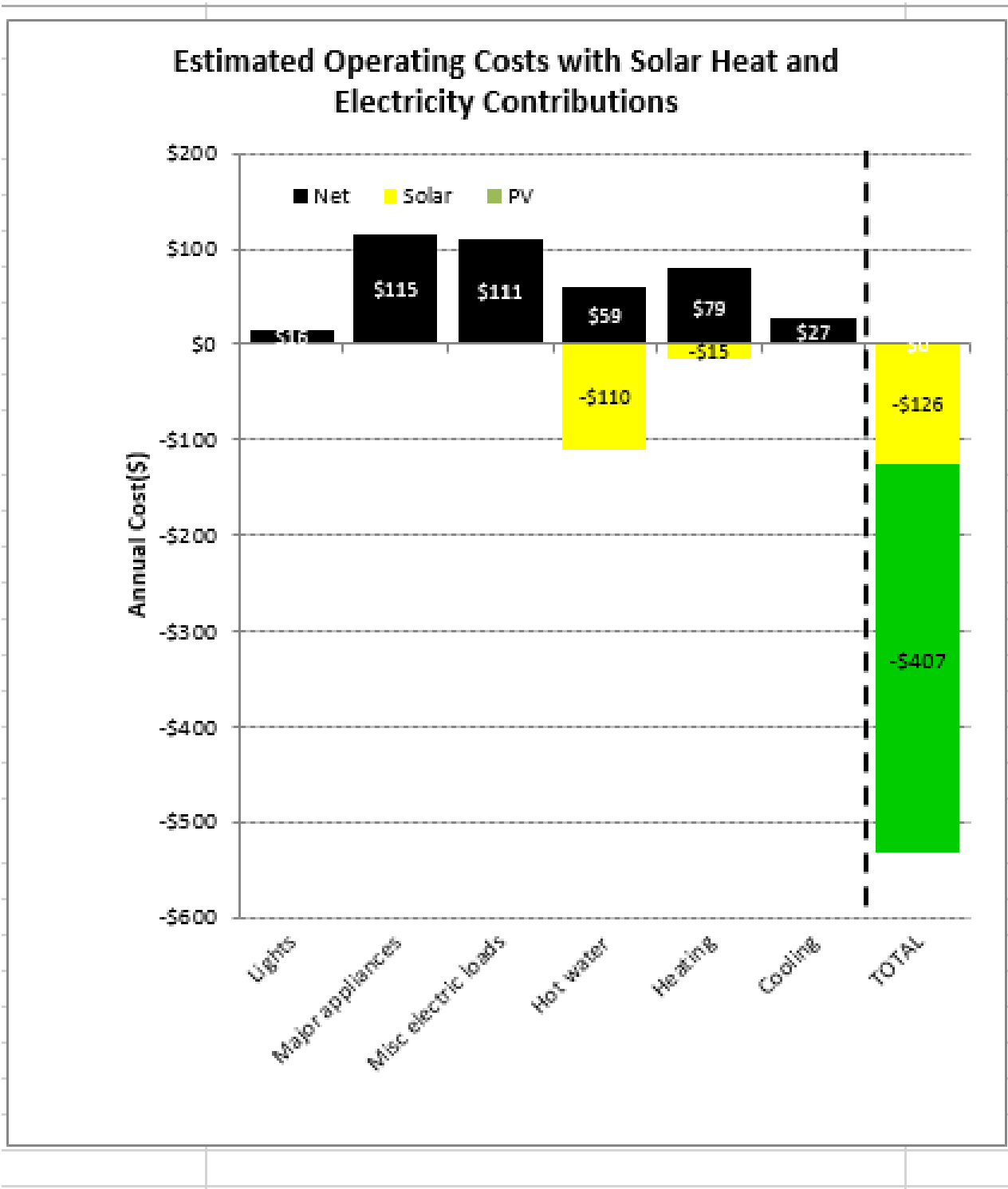
Clarifying the Problem

Final Specifications

ZEH Cost-

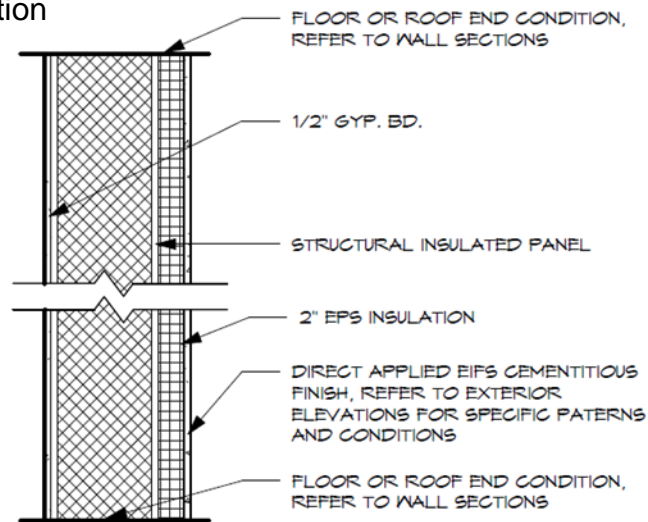
Penn State Center for Sustainability			Zero Energy Home Calculator													
General Info			Heating & Cooling													
Location	Harrisburg		Type of heating & cooling system	Electric heat pump												
Electricity cost (\$/kwh)	0.08		Solar Technologies													
House type	1 story		Size of PV system (kw)	3.87												
Conditioned floor area (sq.ft.)	1123		Solar water heater	Yes												
Number of bedrooms	2		Behavior													
Envelope Details			Water conservation	A lot												
Wall construction	2x6 with R19 batt		Uses clothesline	A lot												
Ceiling Insulation	R40		Thermostat setback	A lot												
Window type	Super double low-e		Heat thermostat setting (F)	60												
Upper floor ceiling area (sq.ft.)	1123		Cool thermostat setting (F)	80												
North wall area (gross) (sq.ft.)	261		Results													
East wall area (sq.ft.)	328		<div>Envelope Heat Transmission</div>  <table><caption>Envelope Heat Transmission Data</caption><thead><tr><th>Component</th><th>Percentage</th></tr></thead><tbody><tr><td>Walls</td><td>49%</td></tr><tr><td>Floor</td><td>19%</td></tr><tr><td>Roof</td><td>17%</td></tr><tr><td>Windows</td><td>11%</td></tr><tr><td>Infiltration</td><td>4%</td></tr></tbody></table>		Component	Percentage	Walls	49%	Floor	19%	Roof	17%	Windows	11%	Infiltration	4%
Component	Percentage															
Walls	49%															
Floor	19%															
Roof	17%															
Windows	11%															
Infiltration	4%															
South wall area (sq.ft.)	387															
West wall area (sq.ft.)	328															
North window area (sq.ft.)	19															
East window area (sq.ft.)	8															
South window area (sq.ft.)	49															
West window area (sq.ft.)	4															
Air tightness	Tight with heat recovery															
Appliances																
Refrigerator	Best															
Clothes Washer	Best															
Dishwasher	Best															
Small Appliance Input																
Extras																
Garage	a. None		Base House Cost	\$ 127,706												
Hot Tub	a. None		PV Cost	\$ 19,367												
Pool	a. None		Upgrade Costs	\$ 12,361												
			Total House Cost	\$ 159,434												

Energy Graph Results-



Insulation Research and Final Specs-

- SIPs- Structural Insulated Panels (SIPs)
 - Panels consist of an insulation foam core sandwiched between two oriented standard boards (OSB)
 - These panels are strong, energy efficient, cost effective and allow for fast on-site installation



- The panels are prefabricated off-site and built in several sizes
- 4'x8', 4'x10', 4'x12', 4'x14', 4'x16'
- The panels can have R-values of 16-48
- We decided to use a 4'x10' panel with an R-value of 19
- This specific panel is 5" thick and costs between \$4-5 per square foot
- We used the same size panels for the roof but with an R-value of 40
- The roof panels (R-value of 40) cost between \$5-6 per square foot and are 10.25" thick
- In the attic we used High Density Cellulose insulation 18" at a depth of 18"
 - ❖ This drawing above was obtained via email from:
Matthew S. Fine Senior Project Manager CPHC®, LEED® AP
Zavos Architecture+Design, LLC
323 West Patrick Street
Frederick, MD 21701
- Other information regarding Sips was acquired from: www.sips.org

Windows final specifications-

- Through benchmarking the team decided on using LowE3 windows
- Research provided that the most square footage of windows should face the south in order to maximize efficiency



American Craftsman 50 Single Hung Fin Windows, 36 in. x 60 in., White, LowE3 Insulated Glass, Argon Gas and Screen

Model # 50 SH FIN Store SKU # 510723

★★★★★ Write the First Review +

\$129.00 / each

7 in Stock at Patton Twp #6841
Aisle 30 Bay 003
(change pick up store)



JELD-WEN Sierra Horizontal Sliding Vinyl Windows, 24 in. x 24 in., White, with LowE Glass and Screen

Model # Sierra SLD 2020 Internet # 202035812

★★★★★ (14) Write a Review +

\$83.54 / each

Item Not Sold at Patton Twp #6841

- Both of these windows are ENERGY STAR Certified
- The 36"x60" has a U-Factor of .29
- The 24"x24" has a U-Factor of .30
- We will have 5 of the 36"x60" (3 on the south elevation, 2 on the north elevation)
- There will be 4 of the 24"x24" (1 on the south elev., 2 on the east elev., 1 on west elev.)
- ❖ these products are available through The Home Depot
- ❖ http://www.homedepot.com/c/Professional_Contractor

Solar Energy Specifications-

- Using the HOMER program we calculated the energy used per month in kW/hours to be:_____
- Provided this value we determined that we would need to produce _____kW/hr. each month
- This was equivalent to 15 solar panels of _____kW capacity
- Pics of solar panels—?????
- Solar panel specs---?????

Appliance specs-

- In order to reduce energy usage the team decided to use ENERGY STAR Certified appliances
- Given the customer's needs, the team decided that we would need the following appliances:
 - Refrigerator
 - Dishwasher
 - Oven
 - Microwave
 - Stove Top
 - Clothes Washer and Dryer
- Again after entering the selected appliance specs into HOMER we were able to calculate the kW/hr. per month that these appliances would use
- See appliance spreadsheet for more info---??????

Project Outline

The team was presented with a challenge of building a Zero Energy Home and given several requirements that must be met in the design of the house including a budget of \$160,000. After reviewing the project specifications, we started to discuss ideas that would help us build the ZEH. We decided to research sample ZEH's so we could grasp the key elements that would go into the design. Then we decided that we would build a one-story house so that we can save energy and building costs. After that, we discussed about number of rooms and the floor layout. The final decision was that two bedrooms, a mechanical room, and 1.5 bathrooms would be sufficient for the family of four. There was some discussion about whether or not we should add basement and garage, and the final decision was to leave these out of the design in order to save a energy and money. Next, we calculated the total cost of building the house and tried to make sensible use of the rest of the budget to solve the energy problem. After that, we focused on the energy criteria. In brainstorming, the team decided to research wind, combined heat & power (CHP), geothermal, and solar sources of energies. The first suggestion, wind energy, was shot down after realizing the cost to build a small wind turbine was about \$50,000, which would use too much of the budget. CHP proved to be more useful in the commercial industry and less effective for residential homes. The third option was geothermal energy, but the problem with this option was that when we tried to calculate the overall price, it was too high. The fourth option was solar energy which was the most feasible option in regards to product costs and energy output.

In this phase of the design, we had decided on the size of the house, floor layout and energy input. The next thing to do was to determine what appliances we would

need and how much energy they would use per month. We determined that the family would need the following appliances: refrigerator, dishwasher, microwave, oven, range, clothes washer and dryer. In order to meet the energy requirements of our ZEH we used only Energy-Star appliances. Next we used the ZEH cost calculator excel spreadsheet to calculate the total energy consumption, solar panel quantity, and the total cost of the house.

Finally we built a three-dimensional physical model of our ZEH using cardboard and made a computerized model of the house using Solidworks. After identifying the customer's needs, generating project specs, performing external research, revising the project specs and developing the final product, our team was able to use the design process in an effective manner in designing our ZEH.

Works Cited

<http://esa.un.org/wpp/unpp/p2k0data.asp>

<http://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3>

<http://batchgeo.com/map/net-zero-energy-buildings>

http://myfootprint.org/en/take_action/reduce_your_footprint/

Windows type: <http://energy.gov/energysaver/articles/window-types>

Energy using tips: <http://energy.gov/energysaver/articles/tips-your-homes-energy-use>

Energy prices of Hummelstown PA:

<https://www.chooseenergy.com/compare/17036/electricity/ppl-electric-utilities-pa/electricity-rates/>

<http://www.iowaenergycenter.org/home-series/>

AQI measurements

http://airnow.gov/index.cfm?action=airnow.local_city&zipcode=17603&submit=Go

<http://www.phila.gov/aqi/>

Source: http://www.energystar.gov/ia/home_improvement/home_sealing/images/S_I-house-LARGE-opt.jpg