# Zero Energy House

Engineering Design 100 Section 2

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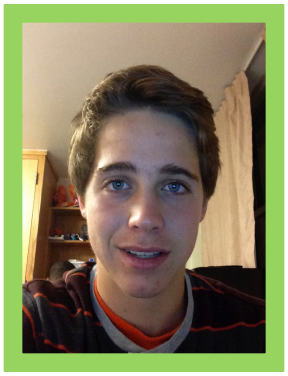
## Team 4

**Mehrin Selimgir**

**Vance McNees**



**Colin Kelly**

**Alexander Khair**

# Summary

Our zero energy home is designed to remove excess wasted energy and supply efficient, renewable green energy. The objective of the house is to supply enough energy for a typical family of four, charge an electric car, and have a net consumption of zero. In order to achieve this our team researched many other zero energy homes and analyzed the types of heating and solar systems used. Through our analysis we decided on the best possible design of our zero energy house. By integrating the concepts of green house building with our design we were able to systematically plan, organize, and develop our zero energy house.

## Introduction

Currently we are reaching the carrying capacity at which our society, our world, can support all of us. As a result, supplying energy and power has been significantly more difficult over the years. Increasing population leads to an accumulation of harmful pollutants that effect our world. It is crucial that we begin to take initiatives to discover sources of renewable and eco-friendly energy. Therefore, zero energy houses are becoming a growing possibility for our future.

## the mission statement

To design a zero energy house, in Philadelphia, for maximum sustainability using green energy building principals.

Put customer needs chart, hierarchy, and matrix here .

Through the assessment of the customer needs and team discussion two main goals were set. The first is to make the house as energy efficient as possible. The second goal is to achieve energy efficiency without compromising aesthetic appeal and customer ease of use. These goals

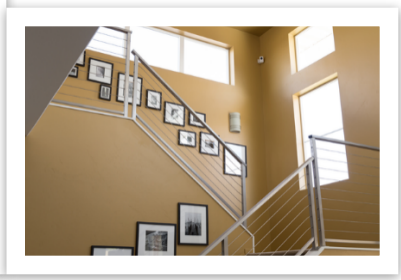
primarily determined the difficult decisions that had to be made about the house such as the number of floors and the size of the PV system.

# External Research

**EDSGN 100 Designing a Zero-Energy Home Team Research & Web Resources Work**

**Utah Zero Energy Home**

| | |
|---|---|
| Location (city, state) | Herriman,Utah |
| House size (floor area in square feet) | 4300 |
| Number of floors | 2 |
| URL of web site where info is found | www.techhive.com |
| Number of occupants | 4 |
| Number of bedrooms | 5 |
| Type of heating system (forced air, hydronic, radiant floor, heat pump, etc. | Solar Thermal System, Structural Insulated Panels |
| Main heating fuel (electricity, natural gas, wood, oil, etc.) | Energy Recovery Ventilator. In addition heating and cooling is provided through forced air from an electric heat pump. |
| Size of photovoltaic system (kilowatts) | Not given |
| Solar water heater (yes or no) | Yes |
| R-value (thermal resistance) of wall insulation | Not given |
| R-value (thermal resistance) of ceiling insulation | Not given |
| Ventilation air heat recovery (yes or no) | Yes ( energy recovery ventilator ) |
| Predicted or measured annual energy use | Not given |
| Any other pertinent info | 3.5 bathrooms, 4-car garage; unsure if information is reliable because neither R-value is stated nor a measured annual energy usage |



## Vermont Zero Energy Home

| | |
|---|---|
| Location (city, state) | Charlotte, Vermont |
| House size (floor area in square feet) | 2800 |
| Number of floors | 2 |
| URL of web site where info is found | http://www.wbdg.org/references/cs_ch.php |
| Number of occupants | 2 (but fits 4) |
| Type of heating system (forced air, hydronic, radiant floor, heat pump, etc. | Radiant heating system |
| Main heating fuel (electricity, natural gas, wood, oil, etc.) | Geothermal (heat recovery ventilator) and passive solar heating |
| Size of photovoltaic system (kilowatts) | None |
| Solar water heater (yes or no) | no |
| R-value (thermal resistance) of wall insulation | 40 |
| R-value (thermal resistance) of ceiling insulation | 56 |
| Ventilation air heat recovery (yes or no) | yes |
| Predicted or measured annual energy use | 5999 kWh |
| Any other pertinent info | Main energy source is a wind turbine, which produces 6222 KWh of energy annually. |

## Massachusetts Zero Energy Home

| | |
|---|---|
| Location (city, state) | Turner Falls, Massachusetts |
| House size (floor area in square feet) | 1,152 sq. ft. |
| Number of floors | 1 |
| URL of web site where info is found | http://www.builditsolar.com/Projects/SolarHomes/MAZeroEnergy/MAZeroEnergy.htm |
| Number of occupants | unknown |
| Number of bedrooms | 3 |
| Type of heating system (forced air, hydronic, radiant floor, heat pump, etc. | Forced air, passive solar heating, and hot air solar panels. |
| Main heating fuel (electricity, natural gas, wood, oil, etc.) | Electricity |
| Size of photovoltaic system (kilowatts) | 4940 |
| Solar water heater (yes or no) | no |
| R-value (thermal resistance) of wall insulation | 42 |
| R-value (thermal resistance) of ceiling insulation | 100 |
| Ventilation air heat recovery (yes or no) | yes |
| Predicted or measured annual energy use | 1,949 KWh |
| Any other pertinent info | |

## Pennsylvania Zero Energy Home

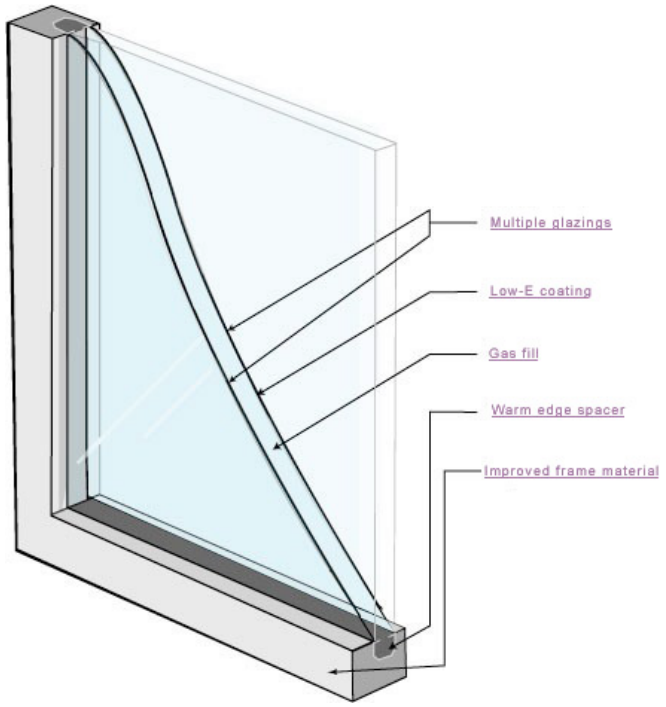
| | |
|---|---|
| Location (city, state) | (Pittsburg, Pennsylvania) |
| House size (floor area in square feet) | 1,850 square feet |

| | |
|---|---|
| Number of floors | 1 |
| URL of web site where info is found | http://www.mnn.com/lifestyle/responsible-living/stories/pittsburgh-gets-its-first-net-zero-energy-home |
| Number of occupants | just says one family doesn't give a number |
| Number of bedrooms | not given |
| Type of heating system (forced air, hydronic, radiant floor, heat pump, etc. | 8,000 watt photovoltaic array, a geothermal heat pump, LED lighting, and "super insulation methods" |
| Main heating fuel (electricity, natural gas, wood, oil, etc.) | not given |
| Size of photovoltaic system (kilowatts) | 8 kw |
| Solar water heater (yes or no) | no |
| R-value (thermal resistance) of wall insulation | not given |
| R-value (thermal resistance) of ceiling insulation | not given |
| Ventilation air heat recovery (yes or no) | yes |
| Predicted or measured annual energy use | not given |
| Any other pertinent info | It gets and energy star HERS rating of a minus 4, 48 similar houses are being planed to be built |

# External research

Windows:

A single pane windows are the most simplistic windows but they have low insulating abilities. More commonly used nowadays are double and triple paned windows which provide significantly efficient insulating abilities. In essence, double and triple paned windows, also known as insulating glazing are double or triple glass window panes which are separated by air or gas filled space. The separation decreases heat transfer and therefore allows for better insulation. As by their name triple-paned windows are windows separated by three glass window panes and therefore further decrease heat transfer as compared to double-paned windows. However, these windows tend to be far more expensive both for installation and replacement. Double-paned windows are more cost efficient and provide enough insulation for our Zero Energy House in Pennsylvania. Therefore, our group decided to use double-paned windows.



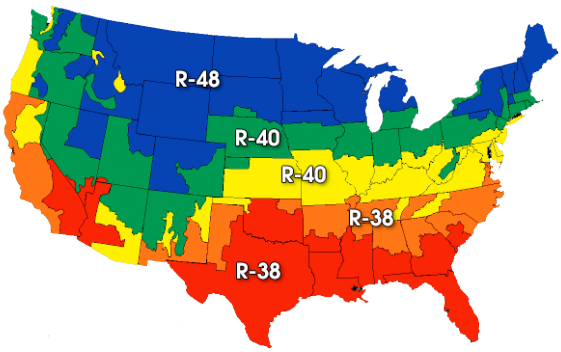

Double-pane windows illustration

Lighting:

Research has shown that the average incandescent light bulb convert less than 5% of the energy they use into visible light, the rest in given off as heat. Incandescent light bulbs use 60 watts in comparison LED lights use only 10 watts and still produce the same illumination of an incandescent light bulb. The team has decided to use LED lights as they are far more efficient and cost-effective.

Insulation:

Insulation is a key factor for a successful zero energy house. Typically fiberglass insulation is used where fiberglass is stuffed into wall cavities however this is a poor choice for a zero energy house. Optimal insulation is achieved through the use of spray polyurethane foam. The spray provides excellent air-sealing and therefore is a popular choice among zero energy homes. However, another method uses cellulose which is significantly more cost efficient. Cellulose insulation is uses recycled material and also provides efficient insulation. Both spray foam and cellulose require professional installation however the team decided to use cellulose insulation as it proved more cost-effective and produced good results for the Pennsylvania zone as shown by the map.

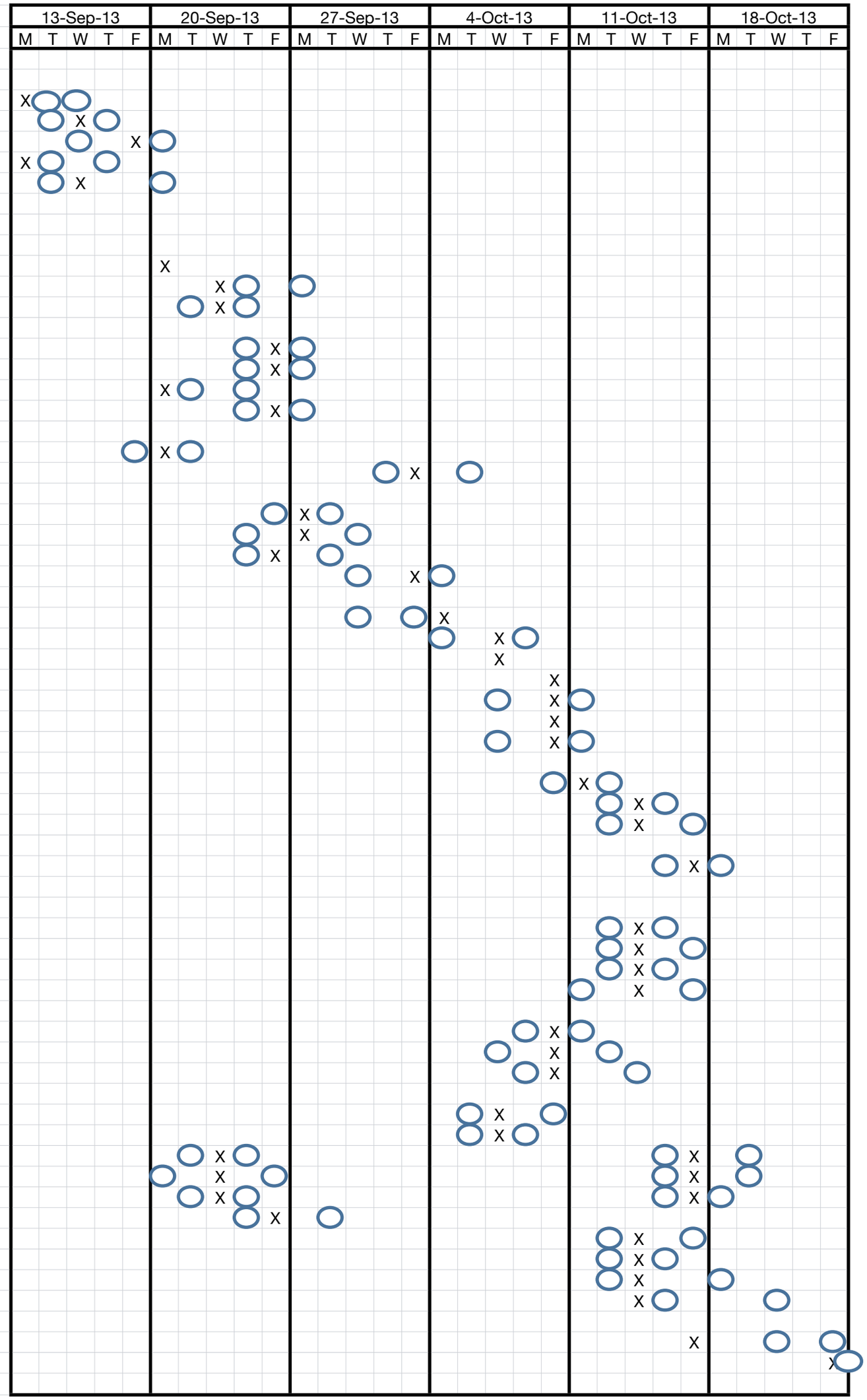



# Conclusion

In the end, a successful final zero energy house was created. The house effectively addressed the needs of the customers by providing maximum renewable, sustainable green energy. The

goals of energy efficiency and customer ease of use were clearly met.The house is built using efficient materials to that will allow the house to produce a net consumption of zero. Through the use of green technology this house will serve as an example of the ability to make our world more sustainable.

| ID | Main Tasks | Intermediate Tasks | Personnel Owner(s) | Week of > Status % complete |
|---|---|---|---|---|
| 1 | **Analysis of Customer Needs** | | | |
| 2 | | Customer Requirements | Vance | 100 |
| 3 | | Selecting City/Location | Colin | 100 |
| 4 | | Background Information on City/Area | Alex | 100 |
| 5 | | Research of ZEH | Mehrin | 100 |
| 6 | | Needs Statements | Mehrin | 100 |
| 7 | | Review | Mehrin | |
| 8 | | | | |
| 9 | | | | |
| 10 | **Establish Target Specifications** | | | |
| 11 | | Product Spec Metrics & Matrix | Mehrin | 100 |
| 12 | | Set target specifications | Vance | 100 |
| 13 | | **Benchmarking** | | |
| 14 | | a. Existing structures | Colin | 100 |
| 15 | | b. Existing renewable energy sources | Alex | 100 |
| 16 | | Develop a cost model | Vance | 100 |
| 17 | | Review | Mehrin | 100 |
| 18 | **Concept Generation** | | | |
| 19 | | Clarify the problem | Mehrin | 100 |
| 20 | | Develop a functional diagram | All | 100 |
| 21 | | **External search** | | 100 |
| 22 | | a. Literature Review | | 100 |
| 23 | | b. Patent Search | | 100 |
| 24 | | Brainstorming | All | 100 |
| 25 | | Review | Colin | 100 |
| 26 | **Concept Selection (Iterate as required)** | | | 100 |
| 27 | | **Concept screening** | Mehrin | |
| 28 | | Prepare the selection matrix | Mehrin | 100 |
| 29 | | Rate the concepts | Colin | 100 |
| 30 | | Rank the concepts | Colin | 100 |
| 31 | | Combine and improve the concepts | Alex | 100 |
| 32 | | Select one or more concepts | Alex | 100 |
| 33 | | Review | Vance | 100 |
| 34 | | **Concept scoring** | | |
| 35 | | Prepare the selection matrix | Vance | 100 |
| 36 | | Rate the concepts | Vance | 100 |
| 37 | | Rank the concepts | Colin | 100 |
| 38 | | | | |
| 39 | | Select one or more concepts | Mehrin | 100 |
| 40 | | Review | Alex | 100 |
| 41 | **Establish Final Specifications** | | | |
| 42 | | Maintenance Reqiurements | | 100 |
| 43 | | Update final specifications | | 100 |
| 44 | | Review | | 100 |
| 45 | | | | 100 |
| 46 | **Design and build** | | | |
| 47 | | Detail Design | All | 100 |
| 48 | | Prototype Construction (CAD/ physical) | All | 100 |
| 49 | | Review | All | 100 |
| 50 | **Report Preparation** | | | |
| 51 | | Abstract/Summary | | 100 |
| 52 | | Introduction | | 100 |
| 53 | | Mission Statement | Mehrin | 100 |
| 54 | | Customer Needs Analysis | Mehrin | 100 |
| 55 | | External Research | Colin | 100 |
| 56 | | Concept Generation | Vance | 100 |
| 57 | | Concept Selection | Alex | 100 |
| 58 | | Design | Colin | 100 |
| 59 | | Conclusions | Vance | 100 |
| 60 | | References | Alex | 100 |
| 61 | **Presentation** | | | |
| 62 | | Prepare the presentation | All | 100 |
| 63 | | Present | All | 100 |
| 64 | **Milestones** | | | |



# Penn State Center for Sustainability

## General Info

| | |
|---|---|
| Location | Philadelphia |
| Electricity cost (¢/kwh) | 5 |
| House type | 1 story |
| Conditioned floor area (sq.ft.) | 1864 |
| Number of bedrooms | 1800 |

## Envelope Details

| | |
|---|---|
| Wall construction | Double 2x4 with 16" Stud |
| Ceiling Insulation | R60 |
| Window type | Super double low-e |
| Upper floor ceiling area (sq.ft.) | 600 |
| North wall area (gross) (sq.ft.) | 540 |
| East wall area (sq.ft.) | 360 |
| South wall area (sq.ft.) | 540 |
| West wall area (sq.ft.) | 360 |
| North window area (sq.ft.) | 54 |
| East window area (sq.ft.) | 36 |
| South window area (sq.ft.) | 108 |
| West window area (sq.ft.) | 36 |
| Air tightness | Tight with heat recovery |

## Appliances

| | |
|---|---|
| Refrigerator | Energy Star |
| Clothes Washer | Energy Star |
| Dishwasher | Energy Star |

Small Appliance Input

## Extras

| | |
|---|---|
| Garage | A. None |
| Hot Tub | A. None |
| Pool | A. None |

# Zero Energy Home Calculator

## Heating & Cooling

| | |
|---|---|
| Type of heating & cooling system | Electric heat pump |

## Solar Technologies

| | |
|---|---|
| Size of PV system (kw) | 5.00 |
| Solar water heater | Yes |

## Behavior

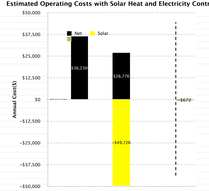
| | |
|---|---|
| Water conservation measures | A. lot |
| Uses clothesline | A. lot |
| Thermostat setback | A. lot |
| Heat thermostat setting (F) | 68 |
| Cool thermostat setting (F) | 75 |

## Results

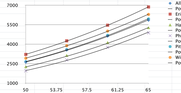
### Envelope Heat Transmission

| | |
|---|---|
| **Base House Cost** | $ 176,695 |
| **PV Cost** | $ 25,000 |
| **Upgrade Costs** | $ 2,650(D3) |
| **Total House Cost** | $ 2,651,(F8) |

## Estimated Operating Costs with Solar Heat and Electricity Contributions




| | HDD | | C | n | FLH | VT | to-clg |
|---|---|---|---|---|---|---|---|
| | 65 | 60 | 55 | 50 | | | |
| Allentown | 5827 | 4607 | 3534 | 2604 | 0.0159 | 1.07 | 740 | 4.4 |
| Erie | 6851 | 5448 | 4244 | 3197 | 0.0375 | 2.901 | 680 | 4.2 |
| Harrisburg | 5224 | 4086 | 3093 | 2221 | 0.00655 | 1.258 | 800 | 4.5 |
| Philadelphia | 4621 | 3577 | 2663 | 1861 | 0.0244 | 1.152 | 820 | 4.6 |
| Pittsburgh | 5930 | 4669 | 3574 | 2635 | 0.0148 | 3.092 | 720 | 4.2 |
| Wilkes-Barre | 6277 | 4994 | 3871 | 2904 | 0.0297 | 2.918 | 630 | 4.3 |




| Walls | R | Cost |
|---|---|---|
| 90 2x4 with R13 batt & 1" foam | 16 | |
| 85 2x6 with R19 batt | 15 | |
| 92 2x6 with R19 batt & 1" foam | 19 | |
| 90 Double 2x4 with 10" foam | 36 | |
| 90 | | |
| 88 | | |
| **Attic** | | |
| R40 | 35 | |
| R50 | 45 | |
| R60 | 55 | |
| **Windows** | | |
| Double low-e | 2.841176 | |
| Super double low-e | 1.846154 | |
| Triple low-e | 5.555556 | |
| **Air tightness** | ACH | Cost |
| Average | 0.5 | 0 |
| Tight | 0.3 | 770 |
| Tight with heat recovery | 0.05 | 1100 |

| HVAC system | Htg Eff | Clg Eff | SEER | |
|---|---|---|---|---|
| Electric geothermal heat pump | 4 | 6 | 20.5 | |
| Electric heat pump | 2 | 4 | 13.7 | |
| Electric hi-eff heat pump | 3 | 5 | 17.1 | |
| Electric resistance | 1 | 4 | 13.7 | |

| GLFs | N | E | S | W |
|---|---|---|---|---|
| Double low-e | 40 | 27 | 53 | |
| Super Double low-e | 7 | 21 | 14 | 27 |
| Triple low-e | 6 | 18 | 12 | 23 |

| | |
|---|---|
| Yes | |
| No | |
| **Conservat** | TSTAT |
| A lot | 8 |
| None | 0 |
| Some | 4 |
| Appliances | |
| Best | 0.7 |
| Energy Star | 0.85 |
| Ordinary | 1 |
| Other appliances | |
| A lot less | 0.6 |
| Less | 0.8 |
| Typical | 1 |

| | DRYER | Water Cons. |
|---|---|---|
| A lot | 0.4 | 0.6 |
| None | 1 | 1 |
| Some | 0.7 | 0.8 |

| | Net | Solar | PV |
|---|---|---|---|
| Lights | $103 | | |
| Major appliance | $36,230 | | |
| Misc electric lo | | | |
| Hot water | $26,776 | -$49,726 | |
| Heating | | | |
| Cooling | | | |
| TOTAL | | | -1672 |




| | Area (sq.ft.) | U-factor (Btu/hr-ft2-F) | UA (Btu/hr-F) | GLF (Btu/hr-ft2) | Cooling Load (Btu/hr) |
|---|---|---|---|---|---|
| Windows N | 54 | 0.2600 | 14.0 | 7.0 | 378 |
| E | 36 | 0.2600 | 9.4 | 21.0 | 756 |
| S | 108 | 0.2600 | 28.1 | 14.0 | 1512 |
| W | 36 | 0.2600 | 9.4 | 27.0 | 972 |
| | | | CLTD | | |
| Walls N | 486 | 0.0278 | 14 | 10 | 135 to-7-ti |
| E | 324 | 0.0278 | 9 | 20 | 180 to-3-ti |
| S | 432 | 0.0278 | 12 | 13 | 156 to-4-ti |
| W | 324 | 0.0278 | 9 | 20 | 180 to-3-ti |
| Roof | 600 | 0.0182 | 11 | 44 | 480 to-27-ti |
| Floor | 600 | 0.0333 | 20 | 9.900000000001 | 198 0.8to+11.3-ti |
| Infiltrate (ACH) | 0.05 | | 13.7 | 17 | 232 |
| Internal gains | | | | | |
| Net Wall Area | 1566 | | | | |
| Total UA | 149 | | | | |
| UA-ns | 111 | | | | |
| NLC | 2671 | | | | |
| LCR | 21.9 | | | | |
| Passive SSF-TC | 0.304 | | | | |
| SSF-DCAI | 0.450 | | | | |

| | |
|---|---|
| Total Cooling Load (Btu/hr) | |
| Windows | 60.8 |
| Walls | 43.5 |
| Roof | 13.5 |
| Floor | 20.0 |
| Infiltration | 13.7 |
| Balance Temp (F) | |
| HDD | |
| Gross Htg Load | F-days |
| Aux Load | kwh |
| Solar Heat | kwh |
| Solar Heating Fraction | |
| Hot water load | 765018 kwh |
| Solar Water Fraction | 0.65 |
| 0.5454545454545 Solar Water heat | 497262 kwh |
| Lights | 1027 kwh |
| Major Appliances | 362,204 kwh |
| Misc Electric Loads | kwh |
| Water Heat | 267756 kwh |
| Heating | kwh |
| Cooling | kwh |
| Total Electric | kwh |
| PV output | 6716 kwh |
| Hours of operation | 1343 |
| Recommended PV | |

| | | | |
|---|---|---|---|
| 378 | 5 | 5 | |
| 756 | 5 | 5 | |
| 1512 | 5 | 5 | |
| 972 | 5 | 5 | |
| 135 to-7-ti | 5 | 5 | |
| 180 to-3-ti | 5 | 5 | |
| 156 to-4-ti | 5 | 5 | |
| 180 to-3-ti | 5 | 5 | |
| 480 to-27-ti | 5 | 5 | |
| 198 0.8to+11.3-ti | 5 | 5 | |
| 232 | 5 | 5 | |
| 103 | 5 | 5 | |
| 36230 | 5 | 5 | |
| 26776 | 5 | 5 | |

| | |
|---|---|
| Floor Area | 1864 ft2 |
| Bedrooms | 1800 |
| HW use | 19878.6 gal/day |

| | Item | Annual Electricity Use (kwh/yr) | | Sensible Fraction | Sensible Electricity Use (kwh/yr) | Non-sensible Electricity Use (kwh/yr) |
|---|---|---|---|---|---|---|
| Ext Lighting | 112 | | 80% fluorescent | 0.00 | 0 | 112 |
| Garage Lighting | 45 | | 80% fluorescent | 0.00 | 0 | 45 |
| Hard-wired Lighting | 696 | | 80% fluorescent | 1.00 | 696 | 0 |
| Plug-in lighting | 174 | | | 1.00 | 174 | 0 |
| Eng | 369 | | | 1.00 | 369 | 0 |
| Water Heat | 26,776 | | | 0.80 | 21416 | 5,360 |
| Other | 100,247 | | | 0.60 | 60148 | 85,210 |
| Dishwasher | 52,067 | | | 0.60 | 31240 | 21,027 |
| Range | 182,152 | | | 0.40 | 72861 | 109,261 |
| MEL from List | | | | 0.90 | | |
| | | | | | | |
| | | | | | | |
| **TOTAL** | | | | | | |
| Sum Non-lighting | | | | Other (no lig | | |
| Lighting | 1,027 | Portion ext lite to non-sensible | | | | |

Source:
Building America Research Benchmark Definition, Updated December 15, 2006
Robert Hendron
Prepared under Task No. BET7.8004
Technical Report

NREL/TP-550-40968
Jan-07
National Renewable

Equation B: Interior hard-wired lighting = 0.8*(FFA * 0.8 + 455) kWh/yr ,
Equation 9: Garage lighting = 100 kWh/yr ,
Equation 10: Exterior lighting = 250 kWh/yr ,
Equation 11: Prototype hard-wired lighting (kWh/yr) = LR*(1.12*FI + 0.279*FF)
where LR = hard-wired interior, exterior, or garage lighting for the Benchmark from Equation B, 9, or 10 (kWh/yr)
FI = Fraction of hard-wired lamps in the Prototype that are incandescent
FF = Fraction of hard-wired lamps in the Prototype that are fluorescent
0.4472

**Table 12. Annual Appliance and Equipment Loads for the Benchmark[a]**

| Appliance | Electricity Consumption | Maximum Load Contribution | Benchmark Load Factor | Annual Load Kwh |
|---|---|---|---|---|
| Refrigerator | 322 kwh | 0.07 kw | 0.40 | 128 |
| Freezer (Refrigerator-Freezer-Freezer) | 0.0 + 0.04 * Fz | 0.07 kw | 0.50 | 0.00 |
| Clothes Dryer (Electric) | 0.53 + 0.34 * Fw | 4.5 kw | 0.10 | 0.00 |
| Dishwasher | 307 + 0.0 * Fd | 0.95 kw (Dishwasher) | 0.05 (Dishwasher) | 15.35 |
| Cooking/Range/Oven (if stand-alone) | 331 + 39.0 * Fo | 1.8 kw (range) | 0.05 (range) | 16.55 |
| Lighting (Electric) | 3410 + 102.1 * Fm | | 0.80 | 2,728 |
| Clothes Washer | 0.0 + 0.0 * Fw | 0.0 + 0.0 * Fw kw | 0.10 | 0.00 |
| Plug-in Lighting | 0.0(DEFAULT) + 0.0 * Fl | | 1.00 | 0.00 |
| Electric Water Heater | 2,500 + 0.0 * Fw | | 0.65 | 2,500 |
| Cooking & Lamps (MELs) | 0.0 + 0.0 * Fc | | 0.85 | 0.00 |
| Other Miscellaneous Electric Loads (MELs) | 0kWh | 0.5 kw | 0.75 | 0.25 |
| Total Electricity Consumption (Excluding Use of MELs) | 6587 | | 0.73 | 5,255 |

**Table 15. Domestic Hot water Consumption by End Use**

| End Use | End Use Temperature | Water Usage | Latent Heat Gain |
|---|---|---|---|
| Clothes Washer | 140 F | 4 x 2 x 2 = 16 gallons | 0 |
| Dishwasher | 140 F | 2.5 x 3.5 = 8.75 gallons | 0 |
| Shower | 105 F | 14.0 x 7.5 = 105 gallons | 7.7 x 105 = 1,155 Btu/day (0.7 x 0.45 x 3.5 x 105 x 8.33 x 60 x 2.5) |
| Bath | 105 F | 3.5 x 7.5 = 26.25 gallons | |
| Sinks | 105 F | 12.0 x 7.5 = 90 gallons | 0 |

* Latent heat gain from appliances are included in the sensible requirements and in the appropriate end use.
** Negligible compared to showers.

| DHW Use Calculator | |
|---|---|
| Washer | 4507.5 |
| DW | 1501.9 |
| Shower | 6476.9 |
| Bath | 1622.7 |
| Sinks | 5769.6 |
| SUM | 19878.6 |
| Adjusted | 11927.2 |

| HW Fraction |
|---|
| 0.769231 |

http://www

| Base House Cost | |
|---|---|
| Size Options | Cost |
| 600 | 86850 |
| 800 | 104640 |
| 1000 | 120400 |
| 1200 | 134520 |
| 1400 | 147140 |
| 1600 | 160720 |
| 1800 | 176400 |
| 2000 | 190000 |
| 2400 | 213240 |
| 2800 | 236600 |
| 3200 | 260480 |
| Y=Mx+B | Where x=Aflr |
| M | B |
| 66.11255263 | 53461.27 |

| PV Array Cost | | |
|---|---|---|
| 5000 | $/KW | |
| | | Pella |

| Window Cost | | |
|---|---|---|
| | 19.5 windows | |
| Double low | 2029 | |
| Super doul | 3042 | |
| Triple low- | 5328 | |
| **Air tightne** | ACH | Cost |
| Average | 0.5 | 0 |
| Tight | 0.3 | 770 |
| Tight with | 0.05 | 1500 |

| Attic Insulation Cost | |
|---|---|
| R40 | 0 |
| R50 | 204 |
| R60 | 444 |

| Appliance Cost |
|---|
| 5720.0 |

| Wall insulation | |
|---|---|
| 2x4 with R13 batt & 1" foam | 1691 |
| 2x6 with R19 batt | 611 |
| 2x6 with R19 batt & 1" foam | 2302 |
| Double 2x4 with 10" foam | 5387 |

Wall incrementsal cost is based on sf incremental cost * SQR(Floor Area)

| Solar water | |
|---|---|
| Y=Mx+B | |
| Slope | Intercept |
| 1462.5 | 1295.833 |

| HVAC | Slope | Intercept | |
|---|---|---|---|
| Electric geothermal heat pump | 1 | 10000 | 11864 |
| Electric heat pump | 1 | 4000 | 5864 |
| Electric hi-eff heat pump | 1.22 | 7200 | 9474.08 |
| Electric resistance | 0.46 | 580 | 1437.44 |

| Garage | Cost |
|---|---|
| a. None | 0 |
| b. Detached 1 car | 17343 |
| c. Detached 2 car | 26070 |
| d. Attached 1 car | 13197 |
| e. Attached 2 car | 22324 |
| f. Built in 1 car | -1662 |
| g. Built In 2 car | -3324 |

| Pool | Cost | Energy |
|---|---|---|
| a. None | 0 | 0 |
| b. 12x30 | 29840 | 1 |
| c. 16x32 | 35744 | 1.5 |
| d. 20x40 | 42600 | 2 |

| Hot Tub | | |
|---|---|---|
| a. None | 0 | 0 |
| b. 4x4 | 4000 | 1 |
| c. 6x4 | 6000 | 1.5 |
| d. 8x4 | 8300 | 2 |

| | |
|---|---|
| Windows: | 3042 |
| Attic Insulation: | 444 |
| Walls: | 5387 |
| Air Tightness: | 1500 |
| Water Heater: | 2633795.8 |
| Heating System: | 5864 |
| Garage | 0 |
| Pool | 0 |
| Hot Tub | 0 |
| Total upgrades costs: | 2650033.4 |
| Appliances: | 5720.0 |

Source: RSMeans Residential Cost Data 2012

Average Class

**1 Story** Location: Page 38

| Cost per sq ft | Living Area sqft | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior Wall | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2400 | 2800 | 3200 |
| Wood Siding | 144.75 | 130.8 | 120.4 | 112.1 | 105.1 | 100.45 | 98 | 95 | 88.85 | 84.5 | 81.4 |
| Brick Veneer | 161.8 | 147.15 | 136.2 | 127.4 | 120 | 115.15 | 112.5 | 109.25 | 102.9 | 98.2 | 94.9 |
| Stucco | 151.1 | 137.6 | 127.6 | 119.7 | 112.9 | 108.5 | 106.15 | 103.25 | 97.4 | 93.15 | 90.3 |
| Solid Masonry | 176 | 159.85 | 147.75 | 137.85 | 129.45 | 124 | 121.05 | 117.3 | 110.25 | 105 | 101.2 |
| | | | | | | | | | | | |
| Finished Basement + | 36.7 | 35.45 | 33.9 | 32.35 | 31.2 | 30.4 | 29.95 | 29.35 | 28.45 | 27.7 | 27.1 |
| Unfinished Basement + | 14.85 | 13.45 | 12.45 | 11.45 | 10.75 | 10.25 | 9.95 | 9.6 | 9.05 | 8.6 | 8.25 |

| Cost for house | Living Area sqft | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior Wall | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2400 | 2800 | 3200 |
| Wood Siding | $ 86,850 | $ 104,640 | $ 120,400 | $ 134,520 | $ 147,140 | $ 160,720 | $ 176,400 | $ 190,000 | $ 213,240 | $ 236,600 | $ 260,480 |
| Brick Veneer | $ 97,080 | $ 117,720 | $ 136,200 | $ 152,880 | $ 168,000 | $ 184,240 | $ 202,500 | $ 218,500 | $ 246,960 | $ 274,960 | $ 303,680 |
| Stucco | $ 90,660 | $ 110,080 | $ 127,600 | $ 143,640 | $ 158,060 | $ 173,600 | $ 191,070 | $ 206,500 | $ 233,760 | $ 260,820 | $ 288,960 |
| Solid Masonry | $ 105,600 | $ 127,880 | $ 147,750 | $ 165,420 | $ 181,230 | $ 198,400 | $ 217,890 | $ 234,600 | $ 264,600 | $ 294,000 | $ 323,840 |
| | | | | | | | | | | | |
| Finished Basement + | $ 22,020 | $ 28,360 | $ 33,900 | $ 38,820 | $ 43,680 | $ 48,640 | $ 53,910 | $ 58,700 | $ 68,280 | $ 77,560 | $ 86,720 |
| Unfinished Basement + | $ 8,910 | $ 10,760 | $ 12,450 | $ 13,740 | $ 15,050 | $ 16,400 | $ 17,910 | $ 19,200 | $ 21,720 | $ 24,080 | $ 26,400 |

**1.5 Story** Location: Page 40

| Cost per sq ft | Living Area sqft | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior Wall | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2400 | 2800 | 3200 |
| Wood Siding | 162.1 | 135.3 | 121.1 | 114.4 | 109.65 | 102.4 | 98.9 | 95.25 | 87.75 | 84.85 | 81.65 |
| Brick Veneer | 170.7 | 141.55 | 126.95 | 119.8 | 114.8 | 107.1 | 103.35 | 99.45 | 91.5 | 88.35 | 84.9 |
| Stucco | 155.8 | 130.8 | 116.95 | 110.45 | 105.95 | 99 | 95.7 | 92.15 | 88.05 | 82.3 | 79.3 |
| Solid Masonry | 190.6 | 156 | 140.25 | 132.35 | 126.7 | 117.9 | 113.65 | 109.2 | 100.05 | 96.55 | 92.5 |
| | | | | | | | | | | | |
| Finished Basement + | 29.95 | 26.15 | 25.05 | 24.25 | 23.65 | 22.7 | 22.2 | 21.75 | 20.75 | 20.4 | 19.8 |
| Unfinished Basement + | 12.9 | 10.1 | 9.35 | 8.8 | 8.45 | 7.85 | 7.55 | 7.3 | 6.7 | 6.4 | 6.1 |

| Cost for house | Living Area sqft | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior Wall | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2400 | 2800 | 3200 |
| Wood Siding | $ 97,260 | $ 108,240 | $ 121,100 | $ 137,280 | $ 153,510 | $ 163,840 | $ 178,020 | $ 190,500 | $ 210,600 | $ 237,580 | $ 261,280 |
| Brick Veneer | $ 102,420 | $ 113,240 | $ 126,950 | $ 143,760 | $ 160,720 | $ 171,360 | $ 186,030 | $ 198,900 | $ 219,600 | $ 247,380 | $ 271,680 |
| Stucco | $ 93,480 | $ 104,640 | $ 116,950 | $ 132,540 | $ 148,330 | $ 158,400 | $ 172,260 | $ 184,300 | $ 211,320 | $ 230,440 | $ 253,760 |
| Solid Masonry | $ 114,360 | $ 124,800 | $ 140,250 | $ 158,820 | $ 177,380 | $ 188,640 | $ 204,570 | $ 218,400 | $ 240,120 | $ 270,340 | $ 296,000 |
| | | | | | | | | | | | |
| Finished Basement + | $ 17,970 | $ 20,920 | $ 25,050 | $ 29,100 | $ 33,110 | $ 36,320 | $ 39,960 | $ 43,500 | $ 49,800 | $ 57,120 | $ 63,360 |
| Unfinished Basement + | $ 7,740 | $ 8,080 | $ 9,350 | $ 10,560 | $ 11,830 | $ 12,560 | $ 13,590 | $ 14,600 | $ 16,080 | $ 17,920 | $ 19,520 |

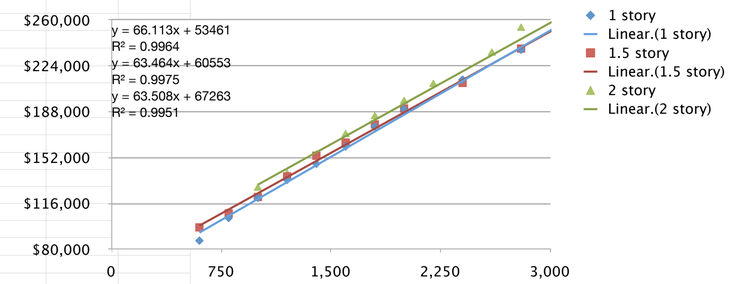
**2 Story** Location: Page 42

| Cost per sq ft | Living Area sqft | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior Wall | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2200 | 2600 | 3000 | 3400 | 3800 |
| Wood Siding | 128 | 115.9 | 110.2 | 106.3 | 102.3 | 98.05 | 95.2 | 90 | 84.5 | 82.1 | 79.9 |
| Brick Veneer | 134.65 | 122.05 | 115.95 | 111.8 | 107.5 | 103.05 | 99.9 | 94 | 88.5 | 85.85 | 83.45 |
| Stucco | 123.15 | 111.45 | 106 | 102.3 | 98.5 | 94.4 | 91.7 | 86.55 | 81.6 | 79.3 | 77.3 |
| Solid Masonry | 150.1 | 136.35 | 129.25 | 124.55 | 119.45 | 114.55 | 110.9 | 103.95 | 97.65 | 94.5 | 91.8 |
| | | | | | | | | | | | |
| Finished Basement + | 21.2 | 20.95 | 20.3 | 19.8 | 19.35 | 19 | 18.65 | 18 | 17.5 | 17.2 | 16.95 |
| Unfinished Basement + | 8.15 | 7.65 | 7.2 | 6.9 | 6.55 | 6.4 | 6.15 | 5.75 | 5.45 | 5.25 | 5.05 |

| Cost for house | Living Area sqft | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior Wall | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2200 | 2600 | 3000 | 3400 | 3800 |
| Wood Siding | $ 128,000 | $ 139,080 | $ 154,280 | $ 170,080 | $ 184,140 | $ 196,100 | $ 209,440 | $ 234,000 | $ 253,500 | $ 279,140 | $ 303,620 |
| Brick Veneer | $ 134,650 | $ 146,460 | $ 162,330 | $ 178,880 | $ 193,500 | $ 206,100 | $ 219,780 | $ 244,400 | $ 265,500 | $ 291,890 | $ 317,110 |
| Stucco | $ 123,150 | $ 133,740 | $ 148,400 | $ 163,680 | $ 177,300 | $ 188,800 | $ 201,740 | $ 225,030 | $ 244,800 | $ 269,620 | $ 293,740 |
| Solid Masonry | $ 150,100 | $ 163,620 | $ 180,950 | $ 199,280 | $ 215,010 | $ 229,100 | $ 243,980 | $ 270,270 | $ 292,950 | $ 321,300 | $ 348,840 |
| | | | | | | | | | | | |
| Finished Basement + | $ 21,200 | $ 25,140 | $ 28,420 | $ 31,680 | $ 34,830 | $ 38,000 | $ 41,030 | $ 46,800 | $ 52,500 | $ 58,480 | $ 64,410 |
| Unfinished Basement + | $ 8,150 | $ 9,180 | $ 10,080 | $ 11,040 | $ 11,790 | $ 12,800 | $ 13,530 | $ 14,950 | $ 16,350 | $ 17,850 | $ 19,190 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 story | wood siding | | | | | | | | | |
| 1.5 | 1.5 story | 1 story | Cost | | 1.5 story | | | 2 story | | | |
| 2 | 2 story | 600 | 86850 | | 600 | 97260 | | 1000 | 128000 | | |
| | | 800 | 104640 | | 800 | 108240 | | 1200 | 139080 | | |
| | | 1000 | 120400 | | 1000 | 121100 | | 1400 | 154280 | | |
| | | 1200 | 134520 | | 1200 | 137280 | | 1600 | 170080 | | |
| | | 1400 | 147140 | | 1400 | 153510 | | 1800 | 184140 | | |
| | | 1600 | 160720 | | 1600 | 163840 | | 2000 | 196100 | | |
| | | 1800 | 176400 | | 1800 | 178020 | | 2200 | 209440 | | |
| | | 2000 | 190000 | | 2000 | 190500 | | 2600 | 234000 | | |
| | | 2400 | 213240 | | 2400 | 210600 | | 3000 | 253500 | | |
| | | 2800 | 236600 | | 2800 | 237580 | | 3400 | 279140 | | |
| | | 3200 | 260480 | | 3200 | 261280 | | 3800 | 303620 | | |

| Floor Area | 1 story | 1.5 story | 2 story |
|---|---|---|---|
| 600 | $86,850 | $97,260 | |
| 800 | $104,640 | $108,240 | |
| 1,000 | $120,400 | $121,100 | $128,000 |
| 1,200 | $134,520 | $137,280 | $139,080 |
| 1,400 | $147,140 | $153,510 | $154,280 |
| 1,600 | $160,720 | $163,840 | $170,080 |
| 1,800 | $176,400 | $178,020 | $184,140 |
| 2,000 | $190,000 | $190,500 | $196,100 |
| 2,200 | | | $209,440 |
| 2,400 | $213,240 | $210,600 | |
| 2,600 | | | $234,000 |
| 2,800 | $236,600 | $237,580 | $253,500 |
| 3,200 | $260,480 | $261,280 | |
| 3,400 | | | $279,140 |
| 3,800 | | | $303,620 |




Location: Page 96

| **Average garage** | Detached | | | Attached | | | Built in (loses house square footage) | |
|---|---|---|---|---|---|---|---|---|
| | 1 car | 2 car | 3 car | 1 car | 2 car | 3 car | 1 car | 2 car |
| Wood | 17430 | 26070 | 34710 | 13197 | 22324 | 30964 | -1662 | -3324 |
| Masonry | 21160 | 30737 | 40315 | 15530 | 25596 | 35174 | -2120 | -3450 |

Location: Page 136

**Exterior Framing (using plywood sheathing)** Should be made into LF to do this, multiply plywood cost *8ft (done by adding 1.11*7, which is like subtracting plywood once and adding 8 times its value)

| | | |
|---|---|---|
| 2x4 16"O.C. | 2.86 | $/S.F. |
| 2x4 24"O.C. | 2.52 | $/S.F. |
| (2)2x4 16"O.C. | 4.61 | $/S.F. |
| (2)2x4 24"O.C. | 3.93 | $/S.F. |
| 2x6 16"O.C. | 3.43 | $/S.F. |
| 2x6 24"O.C. | 2.86 | $/S.F. |

Location: Page 155

| **Window & Door Openings (add)** | | Pella 350 Series | u value | Cost | Cost/sf | Additional Cost over base price | |
|---|---|---|---|---|---|---|---|
| (Feet) | $/L.F. | Double low E 11/16" Natu | 0.34 | 369.99 | 30.8 | 0.000 | |
| 2 | 23.12 | Super double low E 11/16" SunD | 0.26 | 379.24 | 31.6 | 0.771 | Average added cost/sf |
| 3 | 34.68 | Triple low E 1-1/4" Adva | 0.18 | 435.33 | 36.3 | 5.445 | 0 |
| 4 | 46.24 | Pella 350 series specs http://www.pellaadm.com/userdocs/documents/V350-DHGP.pdf | | | | | 4.332083 |
| 5 | 57.8 | | | | | | 14.1 |
| 6 | 78.9 | Triangle/Maru value | | Cost | Cost/sf | Additional Cost over base price | |
| 8 | 104.6 | Double low E LoÊ2-272 – | 0.34 | 660.08 | 55.0 | 0.000 | |
| 10 | 148 | Super double low E LoÊ2-272 – | 0.24 | 754.8 | 62.9 | 7.893 | |
| 12 | 199 | Triple low E Tri-pane Lol | 0.2 | 933.14 | 77.8 | 22.755 | |

**Insulation** Convert to LF by multiplying by 8ft (typical ceiling height)

| | pg 404-406 | | | |
|---|---|---|---|---|
| 1"foam Isocyanurate(R~7) | 1.08 | $/S.F. | 07 21 13.10 | 1640 |
| R13 batt 15" wide | 0.67 | $/S.F. | 07 21 16.20 | 0080 |
| R13 batt 23" wide | 0.63 | $/S.F. | 07 21 16.20 | 0080-interpolated |
| R19 batt 15" wide | 0.73 | $/S.F. | 07 21 16.20 | 0160 |
| R19 batt 23" wide | 0.68 | $/S.F. | 07 21 16.20 | 0180 |
| 10" foam- Celulose Fiber R3.8/ir | 2.66 | $/S.F. | 07 21 23.10 | 0020 |

Where L/F should be considered per 8 ft building height

| | | | |
|---|---|---|---|
| 2x4 with R13 batt | 3.53 | $/S.F. | |
| 2x4 with R13 batt & 1" foam | 4.61 | $/S.F. | |
| 2x6 with R19 batt | 4.16 | $/S.F. | |
| 2x6 with R19 batt & 1" foam | 5.24 | $/S.F. | |
| Double 2x4 with 10" foam | 7.27 | $/S.F. | |
| 2x4 with R13 batt | 3.15 | $/S.F. | |
| 2x4 with R13 batt & 1" foam | 4.23 | $/S.F. | |
| 2x6 with R19 batt | 3.54 | $/S.F. | |
| 2x6 with R19 batt & 1" foam | 4.62 | $/S.F. | |
| Double 2x4 with 10" foam | 6.59 | $/S.F. | |

Pge 406

| **Attic** | Based on ceiling footprint | | | Cost difference versus base cost |
|---|---|---|---|---|
| R40 | 1.3 | $/S.F. | 07 21 26.10 1450 | 0 |
| R50 | 1.64 | $/S.F. | 07 21 26.10 1500 | 0.34 |
| R60 | 2.04 | $/S.F. | 07 21 26.10 1400 | 0.74 |

**Solar Water Heater**

RSMeans Facility Constructions Cost Data, Pg 781

To use this spreadsheet, go down the list and enter the number of each appliance you expect to have in your prototype house

| | Units/ Hshld | Energy/ Unit kWh/yr | Energy/Hshld kWh/yr | Average Cost/ unit | Average Total Cost | Home Office | Units/ Hshld | Energy/ Unit kWh/yr | Energy/Hshld kWh/yr | Average Cost/ unit | Average Total Cost | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fan (Ceiling) | 2 | 50.0 | | 100.0 | 200.0 | Laptop PC (Plugged In) | 1 | 47.0 | | 700.0 | 700.0 | |
| Window Air Conditioner | 0 | 380 | 0.0 | 160.0 | 0.0 | Desktop PC w/ Speakers | 1 | 143.9 | | 700.0 | 700.0 | |
| HVAC Controls | 1 | 20.3 | | | 0.0 | PC Monitor | 1 | 119.8 | | 150.0 | 150.0 | |
| Home Security System | 0 | 195.1 | | | 0.0 | Printer (Laser) | 0 | 92.5 | | 150.0 | 0.0 | |
| Ground Fault Circuit Interrupter | 2 | 6.2 | | 30.0 | 60.0 | Printer (Inkjet) | 1 | 39.0 | | 150.0 | 150.0 | |
| Sump Pump | 0 | 40.0 | | 200.0 | 0.0 | shredder | 0 | 13 | 0 | 70.0 | 0.0 | |
| Heat Lamp | 0 | 13.0 | | 50.0 | 0.0 | DSL/Cable Modem | 1 | 17.6 | | 80.0 | 80.0 | |
| Garage Door Opener | 0 | 35.0 | | 250.0 | 0.0 | Scanner | 0 | 49.0 | | 150.0 | 0.0 | |
| Carbon Monoxide Detector | 1 | 17.5 | | 30.0 | 30.0 | Office Massage Chair | 0 | 7.8 | 0 | 150.0 | 0.0 | |
| Smoke Detectors | 2 | 3.5 | | 20.0 | 40.0 | | | | | | | |
| Garbage Disposal | 0 | 10.0 | | 300.0 | 0.0 | **Bathroom** | | | | | | |
| Doorbell | 1 | 44.0 | | 50.0 | 50.0 | Hair Dryer | 1 | 0.6 | | 50.0 | 50.0 | |
| **Home Entertainment** | | | | | | Curling Iron | 0 | 1.0 | | 40 | 0.0 | |
| First TV | 1 | 215.5 | | 1500.0 | 1500.0 | Electric Shaver | 1 | 12.8 | | 70.0 | 70.0 | |
| Second TV | 1 | 112.7 | | 700.0 | 700.0 | Electric Toothbrush Charger | 0 | 19.3 | | 60.0 | 0.0 | |
| Third TV | 0 | 66.7 | | 350.0 | 0.0 | **Garage & Workshop** | | | | | | |
| Fourth TV | 0 | 52.1 | | 200.0 | 0.0 | Lawn Mower (Electric) | 0 | 42.9 | | 300.0 | 0.0 | |
| Fifth or More TV | 0 | 45.8 | | 100.0 | 0.0 | Pipe and Gutter Heaters | 0 | 53.0 | | 100.0 | 0.0 | |
| Blueray Player | 1 | 71.3 | | 60.0 | 60.0 | Shop Tools | 0 | 26.4 | | 400.0 | 0.0 | |
| DVD Player | 1 | 71.3 | | 50.0 | 50.0 | **Other** | | | | | | |
| VCR | 0 | 71.3 | | 100.0 | 0.0 | Humidifier | 0 | 100.0 | | 150.0 | 0.0 | |
| Wii | 0 | 24.1 | 0.0 | 150.0 | 0.0 | Dehumidifier | 0 | 100.0 | | 200.0 | 0.0 | |
| Xbox360/PS3 | 0 | 63.1 | 0.0 | 300.0 | 0.0 | Water Bed | 0 | 1068.1 | 0 | 1500.0 | 0.0 | |
| Clock Radio | 2 | 14.9 | | 20.0 | 40.0 | Vacuum Cleaner (Upright) | 1 | 31.0 | | 200.0 | 200.0 | |
| Boombox / Portable Stereo | 0 | 16.8 | | 250.0 | 0.0 | Cordless Phone | 0 | 23.2 | | 40 | 0.0 | |
| Compact Stereo | 0 | 112.3 | | 150.0 | 0.0 | Cell Phone Charger | 2 | 77.4 | | 0.0 | 0.0 | |
| Power Speakers | 1 | 24.4 | | 150.0 | 150.0 | Electric Blanket | 0 | 120.0 | | 80.0 | 0.0 | |
| Subwoofer | 1 | 68.3 | | 250.0 | 250.0 | Answering Machine | 0 | 33.5 | | 0.0 | 0.0 | |
| Radio | 0 | 9.1 | | 30.0 | 0.0 | Battery Charger | 0 | 14.8 | | 0.0 | 0.0 | |
| Equalizer | 0 | 14.7 | | 100.0 | 0.0 | Fan (Portable) | 1 | 11.3 | | 40.0 | 40.0 | |
| Satellite Dish Box | 0 | 131.7 | | 0.0 | 0.0 | Air Cleaner | 0 | 65.7 | | 150.0 | 0.0 | |
| Cable Box | 1 | 152.7 | | 0.0 | 0.0 | Surge Protector / Power Strip | 1 | 3.9 | | 20.0 | 20.0 | |
| **Kitchen** | | | | | | Timer (Lighting) | 0 | 20.1 | | 40.0 | 0.0 | |
| Microwave | 1 | 135.1 | | 150.0 | 150.0 | Timer (Irrigation) | 0 | 45.2 | | 50.0 | 0.0 | |
| Chest Freezer | 0 | 300 | 0.0 | 300.0 | 0.0 | Iron | 1 | 53.0 | | 40.0 | 40.0 | |
| Extra Refrigerator | 0 | 475 | 0.0 | 600.0 | 0.0 | Baby Monitor | 0 | 22.8 | | 30.0 | 0.0 | |
| Coffee Maker (Drip) | 1 | 99.3 | | 40.0 | 40.0 | **Fixed MELs** | | | | | | |
| Coffee Maker (Percolator) | 0 | 65.0 | | 50.0 | 0.0 | Pool Heater (Electric) | 0 | 2300.0 | | 0.0 | 0.0 | Already taken |
| Toaster Oven | 0 | 50.0 | | 70.0 | 0.0 | Pool Pump (Electric) | 0 | 2228.3 | | 0.0 | 0.0 | into account |
| Toaster | 1 | 43.7 | | 50.0 | 50.0 | Hot Tub / Spa Heater (Electric) | 0 | 1704.0 | | 0.0 | 0.0 | of based on |
| Waffle Iron | 1 | 25.0 | | 50.0 | 50.0 | Hot Tub / Spa Pump (Electric) | 0 | 460.0 | | 0.0 | 0.0 | your choices |
| Blender | 1 | 7.0 | | 50.0 | 50.0 | Well Pump (Electric) | 0 | 400.0 | | 300.0 | 0.0 | |
| Can Opener | 0 | 3.0 | | 20.0 | 0.0 | | | | | | | |
| Electric Grill | 0 | 180.0 | | 50.0 | 0.0 | | | | | | | |
| Hand Mixer | 0 | 2.0 | | 50.0 | 0.0 | | | | | | | |
| Electric Griddle | 0 | 6.0 | | 40.0 | 0.0 | | | | | | | |
| Popcorn Popper | 0 | 5.0 | | 30.0 | 0.0 | | | | | | | |
| Espresso Machine | 0 | 19.0 | | 180.0 | 0.0 | | | | | | | |
| Instant Hot-water Dispenser | 0 | 160.0 | | 40.0 | 0.0 | | | | | | | |
| Hot Plate | 0 | 30.0 | | 50.0 | 0.0 | **Total MEL Load** | | | | | 5720.0 | |
| Food Slicer | 0 | 1.0 | | 100.0 | 0.0 | | | | | | | |
| Electric Knife | 0 | 1.0 | | 20.0 | 0.0 | Back to main | | | | | | |
| Broiler | 0 | 80.0 | | 150.0 | 0.0 | | | | | | | |
| Deep Fryer | 0 | 20.0 | | 60.0 | 0.0 | | | | | | | |
| Bottled Water | 0 | 300.0 | | 300.0 | 0.0 | | | | | | | |
| Trash Compactor | 0 | 50.0 | | 600.0 | 0.0 | | | | | | | |
| Slow Cooker / Crock Pot | 1 | 16.0 | | 50.0 | 50.0 | | | | | | | |

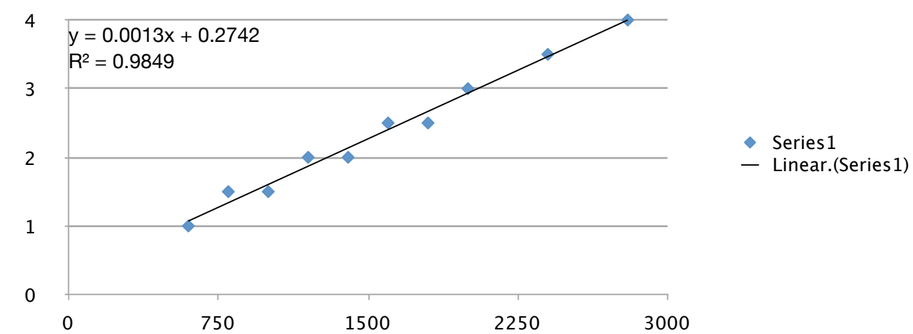
Electric Heat Pump

| Cost | Heat | Coolth | EER |
|---|---|---|---|
| $ | BUT | BTU | |
| 767 | 10200 | 7000 | 11.9 |
| 795 | 10200 | 9000 | 11.4 |
| 820 | 10500 | 12000 | 10.9 |
| 870 | 17100 | 15000 | 9.8 |
| 859 | 12000 | 7600 | 11.7 |
| 919 | 9000 | 12000 | 11.7 |
| 954 | 9000 | 17100 | 11.7 |
| 969 | 11500 | 12000 | 10.5 |
| 1008 | 11500 | 17100 | 10.5 |
| 999 | 14000 | 13500 | 9.6 |
| 1030 | 14000 | 17100 | 9.6 |
| 843 | 9000 | 10200 | 11.4 |
| 969 | 11500 | 11600 | 9.8 |
| 900 | 1200 | 10700 | 10.7 |
| 940 | 14500 | 1700 | 9.8 |
| 1130 | 7200 | 11200 | 13.2 |
| 1550 | 9400 | 16000 | 12.7 |
| 1190 | 11800 | 16000 | 12.1 |
| 1260 | 14800 | 16000 | 11.2 |
| 1240 | 14000 | 13500 | 9.8 |

751.8797

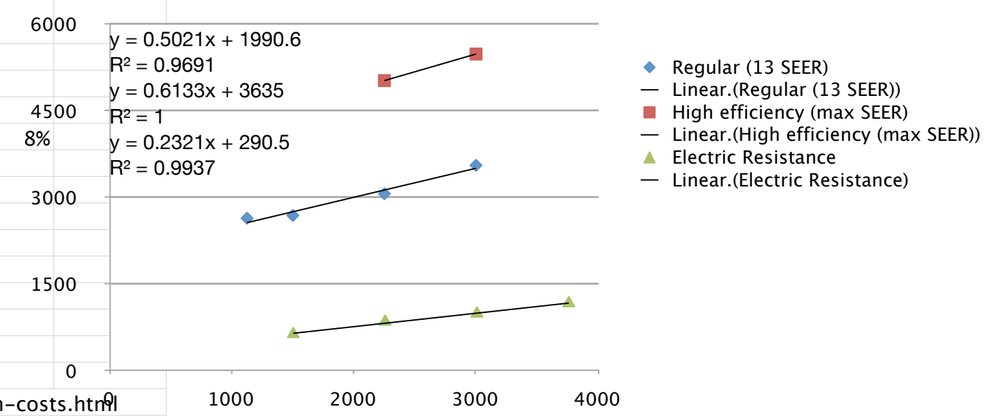
Size per square footag
http://www.alpinehom

| Saize(ft2) | Ton |
|---|---|
| 600 | 1 |
| 800 | 1.5 |
| 1000 | 1.5 |
| 1200 | 2 |
| 1400 | 2 |
| 1600 | 2.5 |
| 1800 | 2.5 |
| 2000 | 3 |
| 2400 | 3.5 |
| 2800 | 4 |
| 3200 | too big for |




http://www.alpinehomeair.com/kitbuilder_new/splitsystem/showgrid.cfm
Kits for Heat Pumps using 'better' option

| | | Area (sf) | Regular (13 SEER) | High efficiency (max SEER) | SEER | Change in energy cost | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.5 ton | 1.5 | 1125 | 2632 | 3175 | 14 | 12 | 0% | | | |
| 2 ton | 2 | 1500 | 2680 | 4020 | 16 | 41 | 2% | 2% | | |
| 3 ton | 3 | 2250 | 3056 | 5015 | 18 | 89 | 14% | 12% | 0% | |
| 4 ton | 4 | 3000 | 3548 | 5475 | 18 | 120 | 26% | 12% | 8% | 8% |




http://www.acdirect.com/goodman_electric_furnaces_.php

| Goodman Electric furnace | | | Rheem Electric Furnace | | |
|---|---|---|---|---|---|
| Cost | CFM | | Cost | Ton | 1ton=400CFM |
| 576 | 800 | | 779 | 1.5 | |
| 612 | 1200 | | 794 | 2 | |
| 647 | 1600 | | 853 | 3 | |
| 674 | 2000 | | 1029 | 4 | |

http://www.heatingsystemguides.com/buying-guides/2012-buyers-guide-for-electric-furnace-prices-sizes-and-installation-costs.html

| CFM | $ | sf | | |
|---|---|---|---|---|
| 600-1000 CFM - $42 | 625 | 1503.759 | Y=Mx+B | where X=size |
| 1000-1400 CFM - $6 | 840 | 2255.639 | Slope | Intercept |
| 1400-1800 CFM - $7 | 980 | 3007.519 | 0.232085 | 290.5 |
| 1800-2200 CFM - $9 | 1160 | 3759.398 | | |

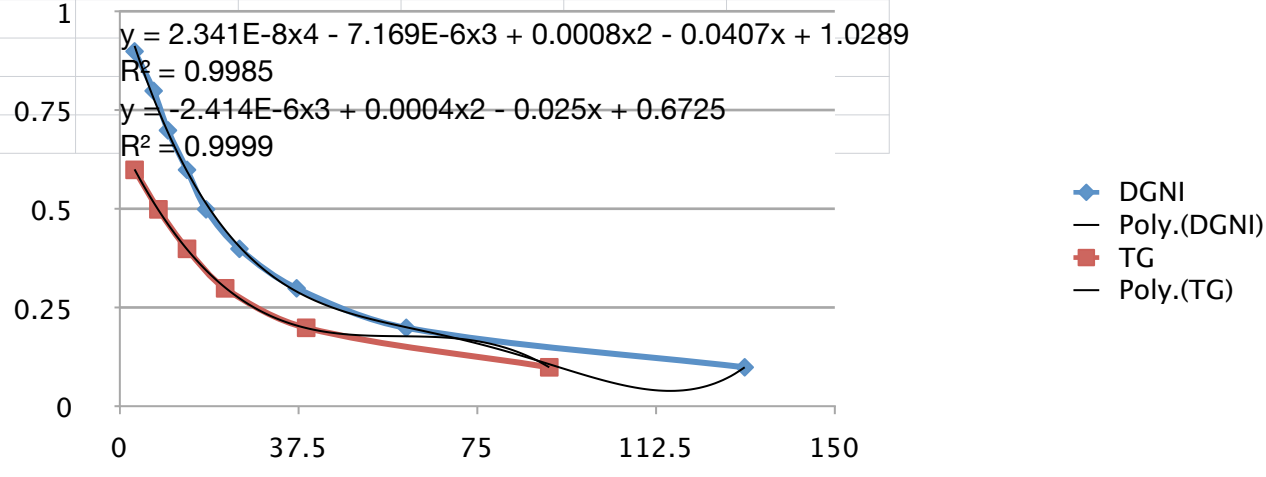
AC Coil Included - Add $400 to each.
5-20kw heating strip - $90
Variable Speed Blower Upgrade - $350
Thermostat - $75

Geothermal installation
Called 2 companies in Lancaster County
home climates- Nathan chambaugh, nshambaugh@homeclimates.com spoke Mnday June 25 at 2:16
Cocalico plumbing and heating- Dale, 717-629-3583 spoke Monday June 25th at 3:38

Nathan: Comparing geothermal to a 16SEER or 18SEER electric heat pump
Typical 2000 SF home costs $200/year in AC, and $600/year in heat
Geothermal can cut those costs by $100/year for AC, $400/year for heat = $500/year saved
Instalation& materials for High Efficiency Heat Pump (HEHP) vs GeoThermal(GT)
HEHP = $8-9K
GT = $14-15K BUT there is a 30% tax credit, save $4K
With a new construction, you can save $800-$1000

Dale: GT: depending on system it can range from $16K to $20K
GT can include hot water, or desuper heater, and storage tanks add to cost
Heat Pumps: $5K to $12K anywhere from 13SEER to 'infinity green' something which is close to GT in efficiency
Recommended that natural gas is a good, cheap alternative to my house :)

| | | | | | |
|---|---|---|---|---|---|
| | | | Predicted | | |
| | 3 glz, noNI | 2 glz, NI, 4 | 3 glz, noNI | 2 glz, NI, 45 | Mass |
| 0.1 | 90 | 131 | 0.100 | 0.100 | |
| 0.2 | 39 | 60 | 0.200 | 0.200 | |
| 0.3 | 22 | 37 | 0.303 | 0.204 | |
| 0.4 | 14 | 25 | 0.400 | 0.388 | |
| 0.5 | 8 | 18 | 0.499 | 0.510 | |
| 0.6 | 3 | 14 | 0.602 | 0.595 | |
| 0.7 | | 10 | 0.673 | 0.695 | |
| 0.8 | | 7 | 0.673 | 0.781 | |
| 0.9 | | 3 | 0.673 | 0.915 | |
| Slope | -0.00196 | -0.00141 | | | |
| Intercept | 0.276471 | 0.284507 | | | |
| | | DGNI | LCR<60 | SSF = 2.34E-8*SSF^4 - | |
| | | | LCR>=60 | SSF = -0.00141*SSF + | |
| | | TG | LCR<39 | SSF = -2.41E-6*SSF^3 | |
| | | | LCR>=39 | SSF = 0.00196*SSF +0 | |



| | | | | |
|---|---|---|---|---|
| RSMeans Facility Constructions Cost Data, Pg 781 | | | | |
| Low Temp-65Gal (1 colector) $ 4,225.00 | | | | |
| Low Temp-120Gal (2 colectors) $ 5,675.00 | | | | |
| Low Temp-120Gal (3 colectors) $ 7,150.00 | | | | |
| Med Temp-85Gal (1 colector) $ 5,050.00 | | | | |
| Med Temp-120Gal (2 colectors) $ 6,850.00 | | | | |
| Med Temp-120Gal (3 colectors) $ 8,975.00 | | | | |
| From RSMean Green Building Cost Data, Pg 301, 303, 305, 307 | | | | |
| Solar Closed Loop, Add-on H.W Sys $ 11,850.00 | | | | |
| Solar Drainback H.W. Sys(120Gal) $ 11,775.00 | | | | |
| Solar Draindown H.W. Sys(80Gal) $ 13,150.00 | | | | |
| Solar Closed Loop H.W Sys(80Gal) $ 1,200.00 | | | | |
| | | | | |
| Dan at Solar Hot | | | | |
| Materials generally half, instalation half, and contractors charge what they want | | | | |
| Small System contractor price 2736.75 | 5472 | | Confirms RS Means | |
| Large system contractor price 3293 | 7200 | | | |
| Small tank $500 | | | | |
| Large Tank $800 | | | | |
| Tank can be assummed to be a part of the house regardless | | | | |
| Some contractors will charge new instalation costs of 700-800 | | | | |
| Some contractors will charge new instalation costs of 2-3K depends on people | | | | |
| | | | | |
| Good estimate for solar given everything | | | | |
| 2 bedroom | 4225 | 2 | | |
| 3 bedroom | 5675 | 3 | | |
| 4 bedroom | 7150 | 4 | | |
| Y=Mx+B | | | | |
| Y= Cost, X=Bedrooms | M | B | | |
| | 1462.5 | 1295.833 | | |

| ID | Customer statements | Design Statement needs | Target Specifications (Metrics) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | I want a zero energy home built anywhere in Pennslyvania. | A Zero Energy Home will be designed in Pennslyvania | The ZEH will be built in Philadelphia facing south |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | I want the home to not only produce enough energy to to support my daliy living expenses. | Use of renewable energy, dominantly solar energy. Solar planels will be installed and positioned for maximum sun exposure. | 20-250 watt solar planels will be installed |
| 8 | I want the home to demonstrate that solar-powered Zero Energy Homes can be made to work well in the Pa. climate | The house will be capable of energy self-sufficiency in the Commonwealth of Pennsylvania | Use of energy star |
| 9 | The house should be big enough for a family of four. | The house is designed to comfortably accomdate a typical family of four. | The house will be 1800 square feet. Consisting of a one floor + basement. (3 bedrooms) |
| 10 | I want the home to be as energy-efficient as possible. | The home is designed for maximum sustainability using green building principals. | Solar planels and LED lights, wood flooring, stone walls. |
| 11 | Although I want the house to be energy-efficient I still want it to look appealing and have it be something that I have pride in. | The house will be designed with an aesthetically pleasing appearance. | The house will be designed with an aesthetic appeal. |
| 12 | I want the house to work  as new even 10 years from now and to have a positve impact. | The house is designed for sustainability; efficiency will not require a significant amount of effort to maintain. | use of energy star applicances and renewable energy (solar). |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
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| 30 | | | |
| 31 | | | |
| 32 | | | |
| 33 | | | |
| 34 | | | |
| 35 | | | |
| 36 | | | |
| 37 | | | |
| 38 | | | |
| 39 | | | |
| 40 | | | |

| | Metric | Net zero energy home | Located in PA | Family of 4 house | Aesthetically pleasing | Use the engineering process | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Need | Need | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 3 | Design a Zero Energy Home | x | | | | | | | | | | | | | | |
| 7 | The house must produce all the energy it needs over a year. | x | | | | | | | | | | | | | | |
| 8 | Design your house for the Commonwealth of Pennsylvania | | x | | | | | | | | | | | | | |
| 10 | Use the engineering design process | | | | | x | | | | | | | | | | |
| 11 | Design your house for a family of four | | | x | | | | | | | | | | | | |
| 13 | Identify and document your customer needs | | | | | | | | | | | | | | | |
| 14 | Make as sustainable as possible using green building principles. | x | | | | | | | | | | | | | | |
| 15 | Design an your house with that iis aesthetically pleasing appearance | | | | x | | | | | | | | | | | |
| 18 | Team work, design a ZEH | | | | | x | | | | | | | | | | |
| 19 | Envision ways to become sustainable | x | | | | | | | | | | | | | | |
| 22 | Identify unsusainable activities | x | | | | | | | | | | | | | | |
| 27 | Learn and create a sustainable design | x | | | | | | | | | | | | | | |
| 28 | Create a sustainable home | x | | | | | | | | | | | | | | |
| 32 | Define your customer needs | | | | | x | | | | | | | | | | |
| 33 | Research ZEH | | | | | x | | | | | | | | | | |
| 34 | Generate ideas for you home and document with sketches | | | | | x | | | | | | | | | | |
| 35 | Narrow your design using engineering process tools | | | | | x | | | | | | | | | | |
| 36 | Develop selection criteria and choose the best concept | | | | | x | | | | | | | | | | |
| 37 | Do detailed design and energy research | | | | | x | | | | | | | | | | |
| 38 | Develop a 3D model | | | | | x | | | | | | | | | | |
| 39 | Produce a scale model that matches your 3D model | | | | | x | | | | | | | | | | |
| 40 | Reflect on the process and produce a final report | | | | | x | | | | | | | | | | |

| | | Concepts | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | | | |
| **Metric #** | **Selection Criteria** | | | | | | | |
| 1 | Net zero energy home | | | | | | | |
| 2 | Located in PA | | | | | | | |
| 3 | Family of 4 house | | | | | | | |
| 4 | Aesthetically pleasing | | | | | | | |
| 5 | Use the engineering process | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |
| 11 | | | | | | | | |
| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |
| | | | | | | | | |
| | Sum +'s | 3 | 5 | 3 | 0 | | | |
| | Sum 0's | 6 | 8 | 5 | 15 | | | |
| | Sum -'s | 6 | 2 | 7 | 0 | | | |
| | Net Score | -3 | 3 | -4 | 0 | | | |
| | Rank | 2 | 1 | 3 | 0 | | | |
| | Continue? | no | yes | no | no | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Concepts | | | | |
| | | | | A | B | C | | |
| Metric # | Selection Criteria | | Weight | | | | | |
| 1 | Energy Efficiency | | 0.5 | 3 | 2 | 1 | | |
| 2 | Insulation | | 0.25 | 1 | 2 | 3 | | |
| 3 | Appliance Efficiency | | 0.1 | 3 | 2 | 1 | | |
| 4 | light watt usage | | 0.1 | 2 | 3 | 1 | | |
| 5 | Cost of production | | 0.05 | 3 | 2 | 1 | | |
| | | | | 2.4 | 2.1 | 1.5 | | |
| | | | | | | | | |
| | | | | | | | | |

Concept A

- 20-250 Watt Solar Panels
- 2 Panel Windows
- LED Lights
- Geothermal Heating

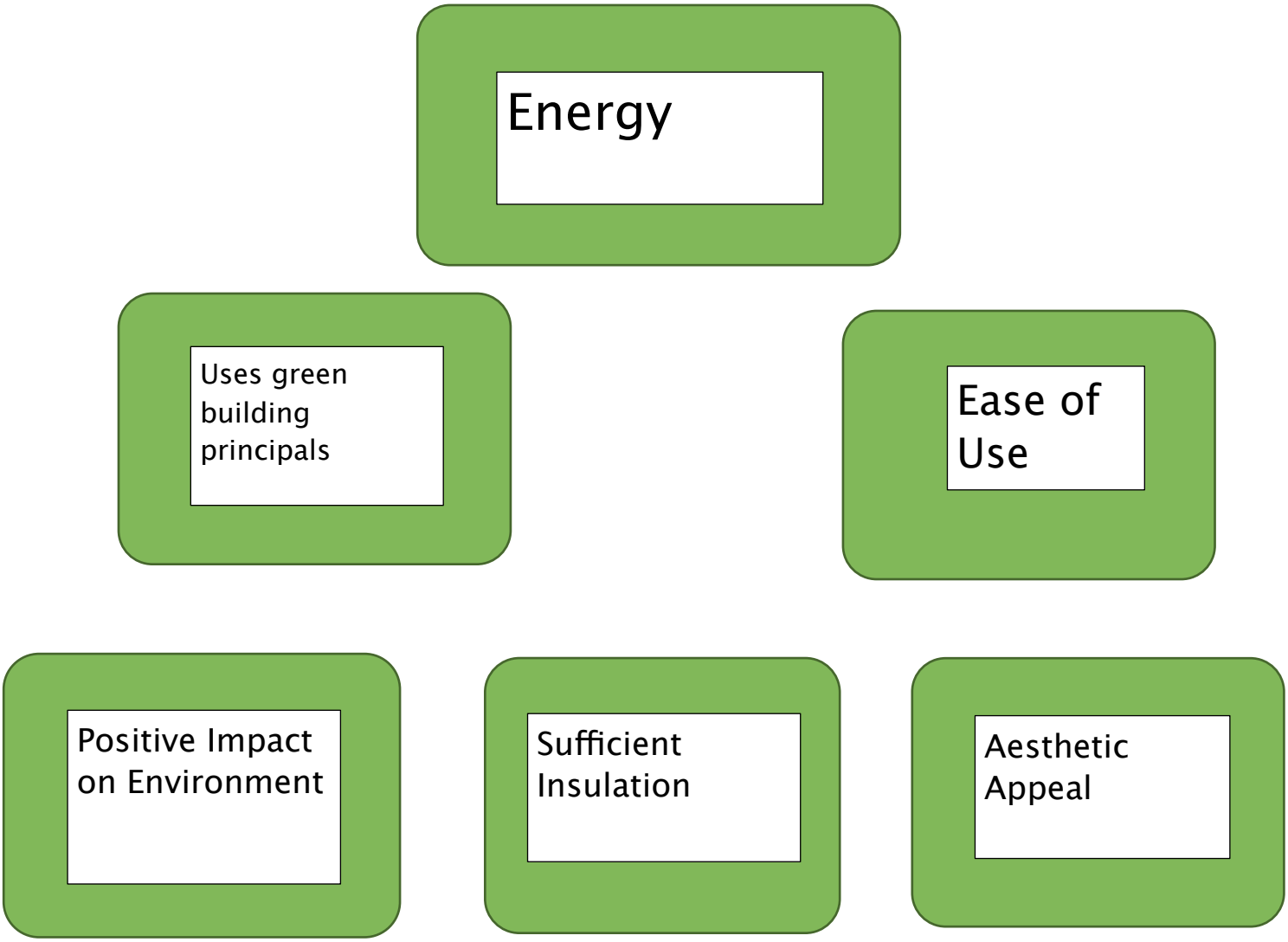
Concept B

- 20-250 Watt Solar Panels
- 3 Panel Windows
- Compact Fluorescent Lights
- Gas Heating

Concept C

- 20-250 Watt Solar Panels
- 3 Panel Windows
- Incandescent Lights
- Gas Heating

# Hierarchy of Customer Needs

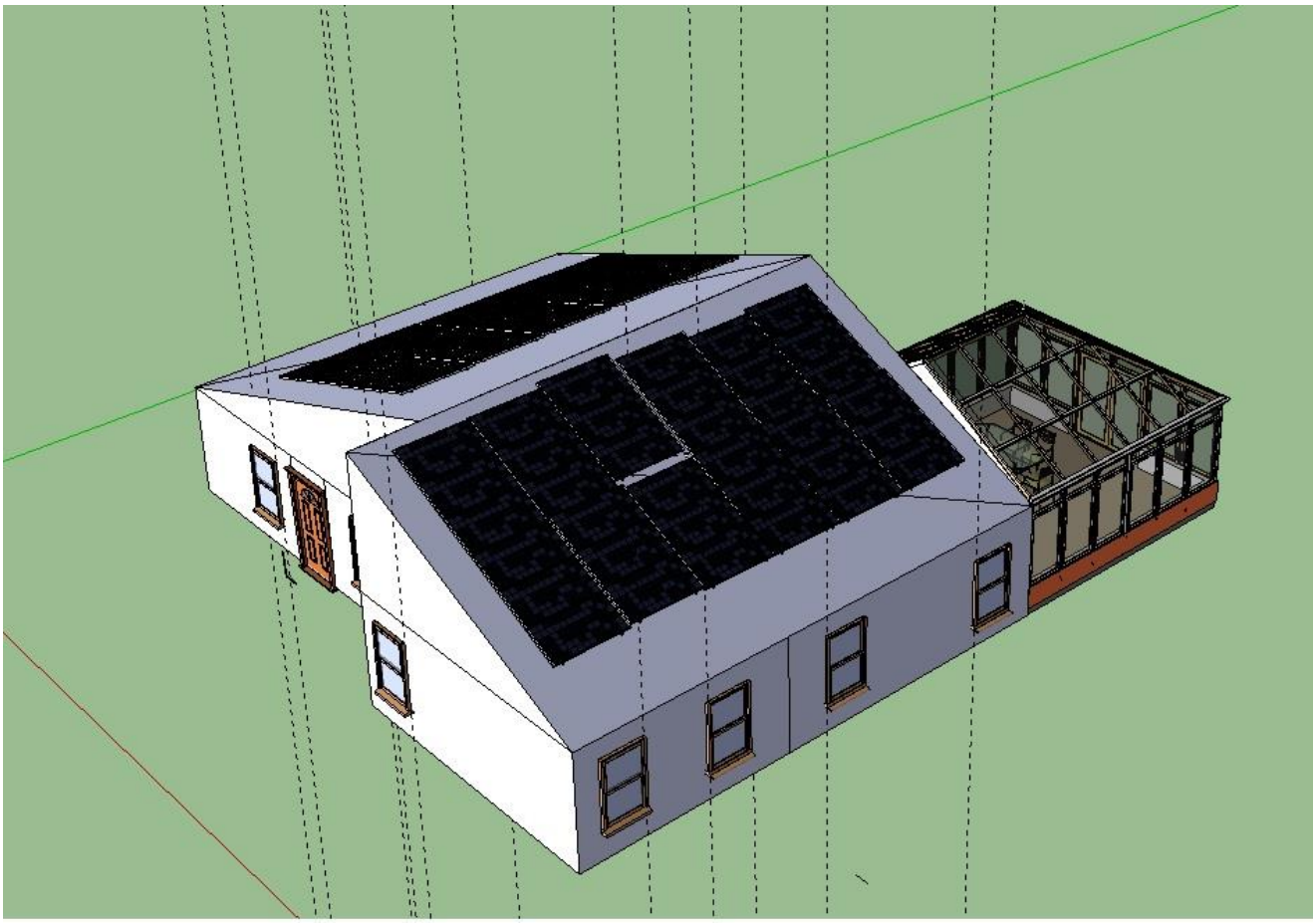


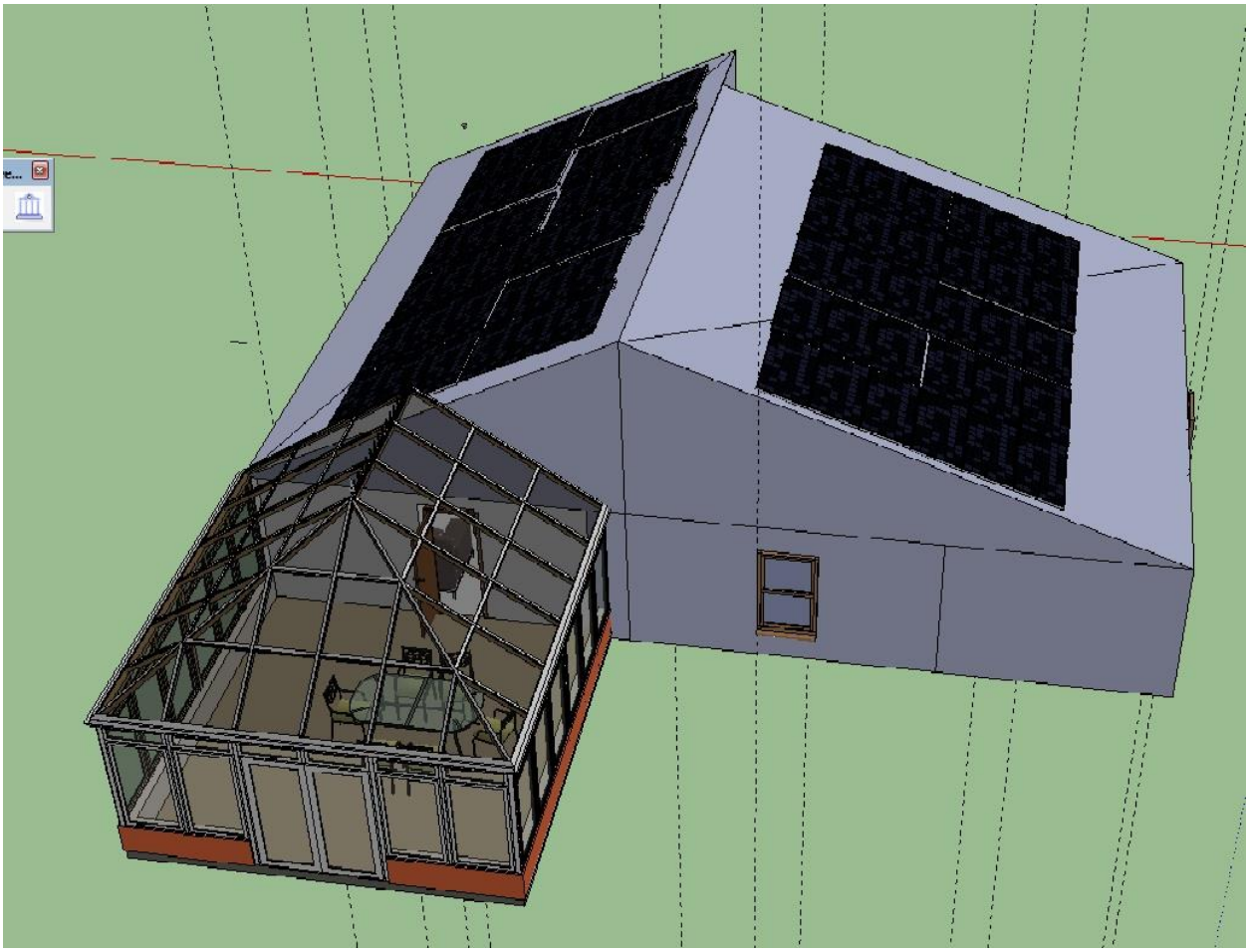
# Floor Plan

| | |
|---|---|
| Sunroom: 18’x18’ | 324 sq. feet |
| Master Bedroom: 16’x16’ | 256 sq. feet |
| Master Bathroom: 12’x12’ | 144 sq. feet |
| Living Room: 20’x20’ | 400 sq. feet |
| Kitchen: 20’x13’ | 260 sq. feet |
| Kid’s Room 1: 12’x10’ | 120 sq. feet |
| Kid’s Room 2: 12’x10’ | 120 sq. feet |
| Bathroom: 12’x8’ | 96 sq. feet |

Total Area of House: 1820 sq. feet

Endpoint





Websites Used:

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