Zero Energy Home Project

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Abstract

This paper is about a "Zero Energy Home" design project. In recent years, excessive electricity consumption and non-renewable energy source shortage have raised global awareness. To achieve "sustainability", which means satisfying current needs while not sacrificing future interests, we design a home, which consumes zero energy in the long run. We use simulation and analysis of field data for current projects. We simulate the layout of our zero energy home, and use field data to calculate the total electricity consumption, generation and total cost. In the mean time, we integrate sustainable and environment-friendly water technologies, smart-appliances and indoor heating systems into our zero energy home to increase energy efficiency. At the end, we will use economical methods to construct a sustainable but still user-friendly home.

Introduction

Energy crisis has become a worldwide problem in recent decades. According to the research from the U.S. Energy Information Administration, the world primary energy consumption has rose from 398 quadrillion Btu to 529 quadrillion Btu between 2000 and 2012. [1]It is estimated that energy crisis will occur as early as 2016. [2] Many families begin to make efforts to improve the situation by building zero energy homes. Most homes use renewable energy to generate electricity. They also try to reduce energy consumption by strengthening insulation of the house, and using high energy-efficiency appliances. As a part of the concept, they also reduce the use of non-sustainable water sources. From the past design, we know we can solve the energy problem in two ways, increase energy supply from renewable source and lower electricity use during daily life. In our design, we try to accomplish the following objectives:

- Energy supply is always greater than energy consumption
- Energy consumption will not exceed the current average household consumption
- Achieve zero cost in the long term.

To create a concrete resolution for our zero energy home project, we will examine the problem in four major aspects: energy production, sustainable water supplies, smart appliances and indoors heating systems. While examining the aspects separately, we will use the design process and try to solve the problem step by step as shown below:

I. <u>Mission Statement:</u> State quantifiable objectives for our design.
II. <u>Customer Needs Analysis:</u> Introduce the location, basic layout, and constraints of our design.
III. <u>External Research:</u> Look for current zero energy home design, and introduce the technologies used.
IV. <u>Concept Generation:</u> Come up with a number of methods in all aspects before designing our home.
V. <u>Concept Selection:</u> Evaluate all ideas we have, and find the most feasible one(s).
VI. <u>Embodiment Design and Final Design Description:</u> Combine all 4 aspects in one; describe how to apply different technologies in our design, and the total cost.

Mission Statement

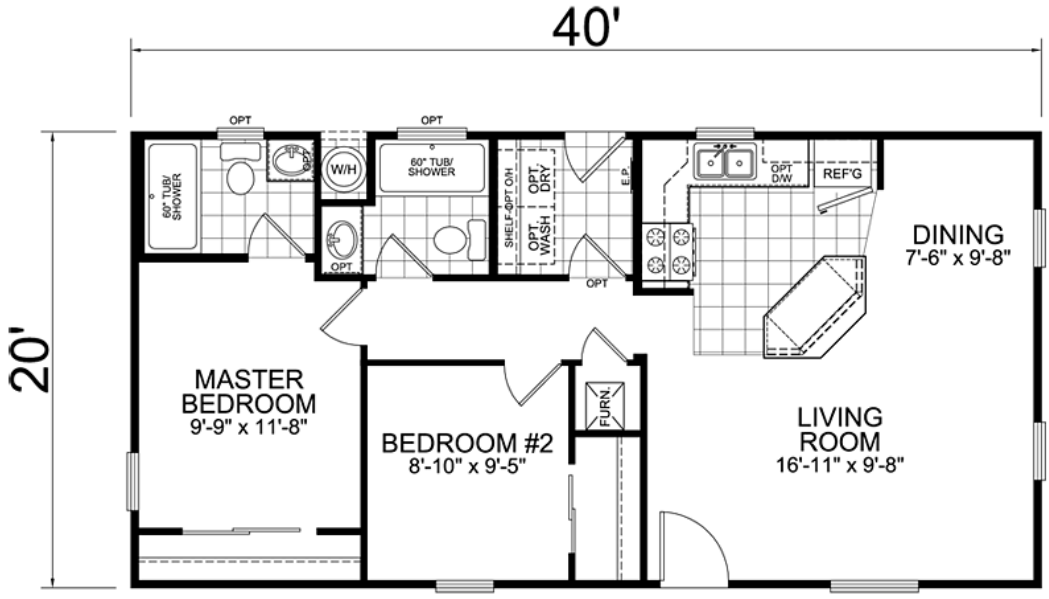
To design a home that is capable of generating enough power to house a family of four while creating sustainable water supplies as well as taking advantage of smart appliances with advanced indoor heating systems by using green building methods and energy efficient concepts.

Customer Needs Analysis

Our customer needs a house to be constructed in Pennsylvania. According to our researches, Harrisburg is the best location to build our house in because of its favorable weather condition. There is a total of 196 days annually in Harrisburg with less than 30% of the sky is covered by clouds. Additionally, the sunlight can reach the ground in average 58% of the time between sunrise and sunset in a day in Harrisburg. This sunny weather conditions favor the use of solar energy. In terms of precipitation, there is 1,039-millimeter rainfall every year, which makes Harrisburg one of the cities in Pennsylvania having the most precipitation. Consequently Harrisburg has the best characteristics to quantify the requirement of "zero energy" which means the ratio of energy generation to energy consumption should be greater than 1.

Our house is required to be built for a four-people family. Considering the level of comfortable living and energy saving, our house has a 800 square feet size. The house is designed for one floor, with 2 bedrooms, 2 bathrooms, 1 living room, and 1 dining area with 1 open kitchen.

The budget for building this house is $200,000. Eventually our plan has to offer a program to build the house while implementing variety of technologies without creating an over-budget.



External Research

A. Energy Production:

Most of the current zero energy homes in the U.S. use solar energy. According to the Solar Energy Industries Association, nearly 600,000 U.S. homes and businesses have applied solar energy for their energy generation. Basically, solar energy generation is related to photovoltaic effect, which means electrons are emitted after sunlight striking on panels, and hence creating current. A solar energy system usually consists

of panels, battery system, inverter and balance-of-system, which includes other installation components. Right now, the average solar panel output ranges from 175 W to 235 W with 11-15% efficiency. There are quite a lot factors affecting the energy production of solar panels, such as amount of sunlight reaching the panels, total area of panels, and the efficiency of the system. Generally, 1 m2 of solar panel can generate 121 kWh annually. As for the system cost, a residential solar system usually ends up costing $15,000 - $40,000.

Apart from solar energy, the most commonly found energy generation method in zero energy home is wind power. The basic working principle of wind power is that wind turbines spin when there is strong wind. It is then connected to alternator and inverter to generate alternating current. Generally, the whole system mainly includes turbines installed on the top of towers, rotor, and other necessary installation equipment. Depending on the wind speed in specific location, homes typically need turbines rated 5-15 kW attached on 80-100 foot towers. The average purchase and installation cost for the wind power system is $48,000 - $65,000.

B. Sustainable Water Supplies:

According to archeological researches, we know that water-harvesting systems were used 6000 years ago in parts of India and the Middle East. Rainwater harvesting systems are still the most common use of sustainable water technology in a global perspective. In today's Germany, more than %55 of the houses use different rainwater harvesting systems. As the survey made by the World Health Organization of the United Nations, %77 of the total urban population in 71 developing countries uses basic water harvesting technologies because of its cheapness and efficiency. In United States of America, the state of Texas has the leading role in the use of water harvesting as a result of the hard work of Texas Water Development Board (TWDB). The results obtained by TWDB points out that the system decreased the unsustainable water consumption by %20 in 5 years.

The septic tank-soil absorption systems are commonly used mostly in rural areas where the public water systems are costly inefficient. According the United States Environmental Protection Agency (EPA), nearly one in four households in the United States depends on an individual septic system or a small community cluster system to treat their wastewater. The system basically is way to treat/purify urine to reuse. However EPA argues that the most of the septic systems in US are installed and mostly forgotten until problems arise. Researches show that %20 of the septic systems cause problem, create pollution and threat public health.

The National Sanitation Foundation (NSF), heavily recommends the next generation of septic system which is called aerobic treatment system (ATS). The main difference between septic system and ATS is that ATS units use a mechanism to inject and circulate air inside the treatment tank, which results a higher level of treatment. According to the NSF Standard 40 shows, ATS produces an effluent with less than 30 mg/L BOD5, 25 mg/L TSS, and 10.000 cfu/mL fecal coliform bacteria. This means the water produced by ATS is clean enough that it cannot support a biomat or "slime" layer like a septic tank.

C. Smart Appliances:

The average energy consumption is 10,044 kWh per year in America. Main electricity consumption is resulted by appliances. Right now, for most zero energy homes, they have smart appliances in their home. Appliances can automatically adjust their power to be more energy efficient, and for the zero energy home right now, most of them have comprehensive sensor in the entire home. The comprehensive sensor is a kind of smart appliance than can automatically supervise the whole home and work collectively with other smart appliance. Many zero energy home can detect motion, brightness, and temperature in the room and share the information with other smart appliances, so that they can adjust their power depend on the information. Right now, for most zero energy homes, they can save up to 4800 kWh per year by using smart appliance.

D. Indoor Heating Systems:

Drain water heat recovery and solar water heaters systems are two domestic technologies accessible

in the marketplace that reduce usage of consumption-supplied energy. There is substantial interest in employing these technologies to minimize energy costs and ecological impact; the actual execution of these technologies in houses remains low (Leidl 244). The necessity for substitute sources of energy is increasingly clear as the distribution of easily exploited fossil energies dwindles and the ecological consequences of using these systems. In this paper, heat pump and solar cells are analyzed as zero-energy home system to promote indoors heating (Leidl 244). Several technologies are available that are proven, accessible and affordable, counting drain water heat recovery and solar water heating. Economics, prior experience, and the necessity to upgrade or sustain an existing technology influence whether possible adopters make a decision to execute a new technology (Leidl 244).

Concept Generation:

A. Energy Production:

Apart from solar energy and wind power, we can use biogas power to generate energy. This method is not commonly used in houses in the U.S., but it is quite popular in some countries, such as China and India. The basic working principle of biogas power is that we put biodegradable waste, like food waste, sewage, and human waste, into anaerobic digesters. Biogas will be formed in 10-30 days. Then, the gas would pass through a desulfurizer, and lastly produce energy by using generator.

Depending on the functionality of anaerobic digester and the composition of waste, 1 ton of waste can produce 367-m3 biogas, while 1 m3 of biogas can generate 6 kWh energy. A typical domestic biogas power project costs about $7,500 - $25,000.

Besides these, we try to make good use of the collected rainwater. So, we think of the possibility of installing water turbines down the rainwater pipe. By doing so, rainwater flows through the turbines, causing the turbines to spin. Then, we connect the turbines with an alternator to generate electricity.

B. Sustainable Water Supplies:

In today's world, demands in usable water are increasing in an exponential way because of the extreme speed of population growth. According to United States Environmental Protection Agency, water consumption has tripled in the last 50 years. We know that in the last five years, at least 36 states in United States faced on water shortages, even under non-drought conditions. Consequently, the use of sustainable water technologies has an essential place in the Zero Energy Home concept.

Most of the Zero Energy Homes in United States use a water harvesting system. It is reported that most of the owners gave a good feedback to companies. We see that %70 of the tanks are located underground because of the expensive use of land.

We have multiple options to treat the urine and other waste of water. Although the septic system is relatively inexpensive and easy to use, ATS has an efficiency advantage. It is also stated that 2/3 land areas in USA are not suitable for septic system including Harrisburg area. Additionally, even some states don't permit the use of aerobic system; Pennsylvania newly accepted the aerobic system as a water technology.

High-pressure reverse osmosis system is another technology, which is currently developing in Mediterranean area. The system basically desalinates the brackish water (for example the water of Susquehanna River or Pennsylvania Canal).

Another technology recently commercialized is the biopipe system. It is mostly use in developed industrial areas to maintain public environment policies. The main item in the system is the wide pipes, which clean the wastewater when it flows in it. Although companies try to enter the apartment and house markets, we couldn't find a concrete feedback from customers.

C. Smart Appliances:

Appliances are main source of electricity consumption. We consider that every appliance in our zero

energy home to be efficient and energy saving. We mainly have two choices. One is to use just energy star appliances without Internet connection; another is to use smart appliances with Internet connection.

Energy star appliances can already save much energy, but it could not connect to Internet, and energy appliances are not smart, they can not work intelligently.

As for smart appliances, it can connect to internet in the room, which make it accessible to control the appliances in the room remotely and even people do not control them, with internet connection, all the appliances can automatically share their data with centralized control in the room. After analysing all the data, the centralized control can give the feedback to all the appliances in the room, let them adjust their power to be more energy efficient.

Collaborating with centralized control in the room, appliances would be much more energy efficient, and with centralized control, our room can be more intelligent and can do something normal appliances can not do, like sensor can automatically detect the brightness and the blinds can automatically adjust itself, it can help us save a lot of energy in small aspects.

D. Indoor Heating Systems:

There are a rising concentration and push concerning zero energy homes by national and state governments and responsible bodies. A net-zero energy residence is defined as a housing building that integrates energy efficient cover design and equipment choice with Internal renewable energy production approaches such as solar electric or solar thermal systems. The choices are adopted to attain net-zero annual energy utilization on a source energy foundation. This idea has been welcomed by the Department of Energy's Building Technologies Building America strategy as its long-term objective. Most investigations of efficient homes or zero energy residences concentrate on electric consumptions. This analysis proposes that the accelerated gas utilization decrease make the consequence of gas utilities an impending reality. However, heat pump and solar cells are more applicable both in economic and environmental terms. Residences that utilize solar photovoltaic and solar thermal technologies to produce energy needed known as net zero energy solar homes. Numerous design strategies exist that assist designers establish form and course of buildings along with a suitable combination of thermal windows and mass. In addition, many components are indispensable to attain the net zero energy goal, comprising solar thermal collectors, Photovoltaics, and effective HVAC systems.

Solar Combisystems is a fascinating option for heating in combination with auxiliary heating by biomass, electricity, or other energy. It uses an active solar thermal antenna for heating domestic hot water and space heating. Pump heaters provide users with continual hot water at high devices energy-efficient usage compared to storage appliances. Analysis demonstrates the annual thermal usage of systems with smart solar tanks is about 5%-35% more with thermal performance. Thermal solar power systems can exchange solar energy to heat at a rate bigger than 80%.

A new solar photovoltaic/loop-heat-pipe heat pump system fabricated and designed for both hot water and electricity production. Given the precise indoor assessment conditions, temperature of the Al-alloy integrated PV cells was experimental at approximately 62.4 °C. This temperature that was 5.2 °C lesser of the TPT integrated PV cells, and its equivalent PV effectiveness was approximately 9.18%, almost 0.26% more than the TPT integrated type. Performance of a new LHP and connected solar PV/T technology presents numerous remarkable benefits over the accessible straight heat pipe, LHPs, associated solar thermal generation, and PV/T-systems.

Concept Selection

A. Energy Production:

As for the wind power, the average total cost is the highest amongst all possibilities. (Refer to External Research). More importantly, the wind speed in Harrisburg doesn't favor the use of wind power. In Harrisburg, the average wind speed is 7.5 mile per hour (mph). However, based on the power curve against wind speed, a typical wind turbine requires a cut-in speed of 3.5 m/s (7.83 mph). It shows that if the wind

speed is constantly below 7.83 mph, the turbines would not spin, so wind power does not work. So, wind power is not a feasible energy generation method for our home.

As for the water turbine method, it is proven impractical as well. According to a research, we can generate 1.5 kWh of energy in a 7-meter high house assuming that annual rainfall is 0.43m. Although the precipitation in Harrisburg triples the experimental value in this research, the energy generated is still far below the average energy consumption (10,044 kWh).

As for solar energy, it is the most popular energy production method in the existing zero energy home projects. It is because the whole solar energy system is not too complicated. There are many companies in the market that sell panels and provide installation service. The sunlight amount in Harrisburg also makes solar energy usage favorable. Most importantly, the average price of a national PV installed system has declined by 11% year-by-year. This is good news for our project providing that our project has a budget constraint. Therefore, in terms of production level of energy and cost, solar energy seems an ideal method.

Lastly, as for biogas power, despite its unpopularity in the U.S., it is still an economical method. Biogas power is one of the cheapest among other methods. The system requires a low maintenance cost. The energy production process itself also demonstrates a "green" concept that is using trash to produce energy instead of throwing them away. Thus, biogas power can be a secondary source of energy assisting solar energy in our home.

B. Sustainable Water Supplies:

As a group decision, we want to take advantage of all the possible technologies we can implement in our concept. As we mentioned in the mission statement, our final goal is to decrease the unsustainable sources and in the mean time, to maximize the use of water produced from sustainable systems.

The main source of water will be the rainwater harvesting system. In this part, Harrisburg's rainfall parameters create a real opportunity to sustain clean water for our concept. However the rainfall decreases in the summer and the system becomes mostly inactive. That proves the point already made that we need reinforcement systems to create a sustainable water concept.

The supportive technology will be the ATS. Although it seems to be inexpensive in short term, the systems will pay-off in a long-term, sustainable future. Additionally, the system creates a source of %100 renewable water for all seasons. When we look at the costs of electricity to pump oxygen into the water, we see that it can be covered by the other energy production technologies in the concept.

The second alternative supportive technology is the high-pressure reverse osmosis system. Although it is the most beneficial way to desalinate water, the land located in the cost of Susquehanna River and Pennsylvania Canal is highly expensive to buy. If we plan to build the house in the cost of the river, this will cause an over-budget, which doesn't maintain the customer needs. Consequently this system is not convenient to use in this budget.

In this concept, the biopic will not be used as a supportive technology. The first reason is the lack of reliable feedback from customers. Until we have enough details how the system had implemented in a small-scale project, we can't take any risk in a small budget.

C. Smart Appliances:

We do some research about these two options. Take refrigerator for an example. We search online and found that with the same function, the energy star refrigerator is about 200 dollars cheaper than the smart Internet connected refrigerator. But, the energy comes first. For refrigerator, smart refrigerator can save up to 30% energy than old appliances. Our centralized sensor will detect brightness, temperature, and other data in the room. If the temperature is too high, it can automatically tell the air conditioner to turn the temperature down. If the comprehensive sensor find the brightness in room is enough for reading and normal activities, it can tell lights in the room turn the brightness down and automatically turn the blinds up to make it more comfortable. For our purpose, we think even smart appliances are more expensive than energy star appliances, but energy star appliances are not smart enough to adjust their power to save energy in the room. On the contrary, Internet connected appliances can share data with centralized control, the centralized

control can smartly tell appliances how to work properly.

We search a lot of data about how many energy smart appliances can save, we find that there are some useful information. We find that turning the blinds in our room down when the temperature and opening the blinds when there is no enough bright can save up to 300 KWh per year, so with collectively work with centralized in our room, we can save a huge amount of electricity. (http://energysavings.togetherwesave.com/add-up-your-savings)

Based on the data we have, we calculated all the energy in our room we can save, we come up with 4800 kWh per year, this number is huge, because we have centralized sensor, which can smartly work with all the other appliances, it can even unplug all the appliances in the room to save energy.

Since the electricity fee in PA is about 7 cents per Kw. So we use smart appliance in our home, we can save 4800 kWh per year, which is 350 dollars per year.

All in all, even though smart appliance with Internet connection are more expensive than energy star appliances, but the energy smart appliances can save is significant, and for a long term project, we can save a lot of money on buying electricity. So, we opt to use smart appliances, we think it worth it.

Embodiment Design and Final Description

To create a plausible exterior design, the embodiment design should be highly and precisely thought. Our very first goal is trying to hide technologies by combining them and by using underground for large equipment.

In our house, there is a set of fixed 4 kW solar panels on the roof. The panels would be tilted at a 50-degree from the vertical, which is believed be the optimal angle in Harrisburg throughout the year. The whole solar panel set would be in around 50-m2 sizes. Under the panels, there would be a battery system, and the system would be connected to inverter and finally to the household electric wires. Assuming that the system has 14% efficiency, the energy produced annually would be 6340 kWh. Our secondary source of energy is from biogas power. All biodegradable waste would be transferred to an anaerobic digester in 2-m3 volume, which is placed underground. After biogas is formed, a 10W biogas pump would push biogas to pass through 1pc desulfurizer and reach a 2.8kW biogas electric generator. Lastly, all the energy generated would be connected to the household electric wire and provide electricity to the family.

By using the average household garbage amount and percentage of biodegradable waste from all waste, it is estimated that the biogas system can generate 2,810 kWh every year.[1] Therefore, the total energy generated using solar energy and biogas power is 9150 kWh every year.

Additionally to solar panels in the roof, we will put narrow canals along the sides to collect rainwater. The water flows through the canals, which are connected to tank where the rainwater will be collecting. Tank will be putted underground to sustain room temperature and to not use the land. The tank's capacity will be approximately 200 gallon. If we can collect 200-gallon rainwater during the winter as we predict, this system will decrease 421-gallon use of nonrenewable water to 221-gallon, which creates %48 decrease in total.

ATS will connect all the water waste pipes to one treatment unit located underground. The waste will be purified by the mechanism in the system, which uses the electricity produced by the solar panels. The purified water will be collected in the same tank we collect the harvested rainwater. The reason behind this idea is to reduce electricity needed by the pump to transfer water from underground to the house. ATS will work in all year long and creates min. 82 gallon of water per day.

To decrease the use of water while saving it, we will place specific facets to each bathrooms and kitchen. These faucets are specifically designed to reduce the flow speed of water by decrease it to 1 gallon per minute. This low cost addition will create a %5 decrease in total use of water. With the implementation of the rainwater harvesting system and ATS with special faucets, the yearly use of non-sustainable 153.244-gallon water will dramatically decrease. We are expecting a %77 decrease in use of non-sustainable use of water in winter and fall. As a result of decrease in rainfall in spring and summer, the expected decrease in

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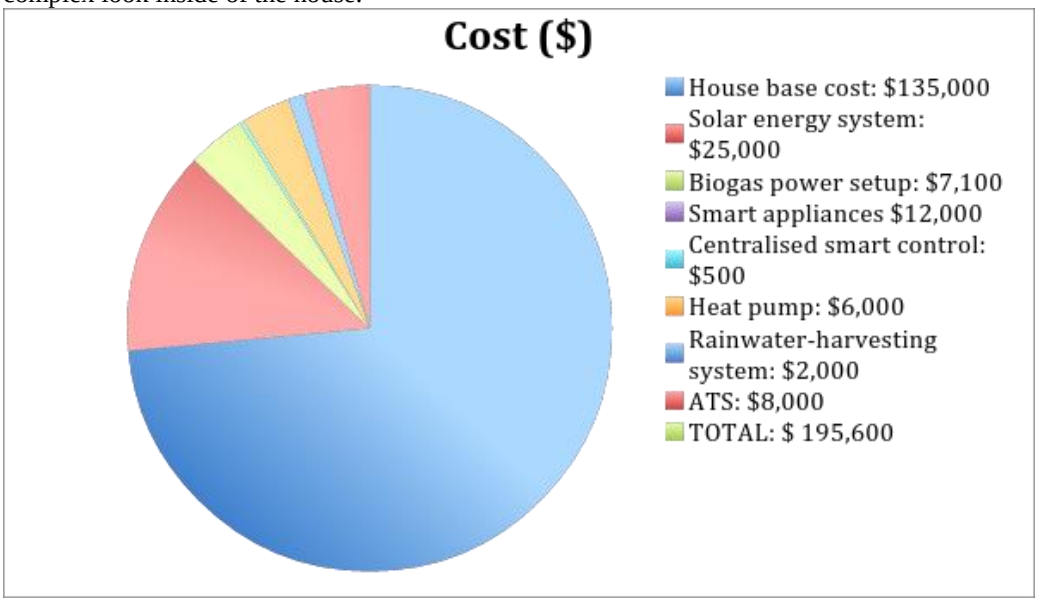
[1] 4(people) * 726(kg) * 40% / 910(kg) * 367 m3 * 6 kWh = 2810 kWh,
(Average American create 726kg of waste per year, 40% of waste is biodegradable, 1kg of waste can create 367 m3 biogas, 1 m3 biogas can generate 6kWh)

non-sustainable water is %45.

As minor extensions, all the appliances are connected to Wi-Fi in the home, and all the appliances are centralized controlled by comprehensive sensor in the room, which can automatically detect brightness, temperature, and motion in the room. It can control all the lights to adjust to the brightness that most energy saving, it can tell air conditioner to adjust its temperature. It can detect people's motion in the room, and automatically turn the lights off to save energy. Besides, people can easily access to comprehensive sensor in the room, so that people can control the entire appliance to further save energy.

To create the heat pump system, we will put the pump underground then create a system of heating inside of the house. As we already mentioned, all the system will be hidden inside of the walls to avoid a complex look inside of the house.



Guidelines to customers:

- It is encouraged that customers can separate biodegradable waste from ordinary waste when throwing wastes. Biodegradable wastes include human waste, sewage, food waste, etc. This could facilitate the functions of biogas power generation.
- It is better not to include precipitate in the sewage. Try the better to filter them out. This could facilitate the function of aerobic treatment system.
- It is better to have a stable internet connection between appliances and cell phones.
- Keep the temperature of air-conditioners and heaters at a reasonable temperature, otherwise it consumes an excessive amount of electricity and creates an unnecessary heat loss.
- Bear in mind that everything we do would impact the environment.

Conclusion

Eventually, our design features on a 4-people living house that consumes zero energy in the long run. Rather than using fossil fuels to generate electricity, using non-sustainable water sources as well as using inefficient appliances and heating systems, it is greener and mostly cheaper to use renewable and sustainable technologies. Connectedly, technologies, which we decided involve in sources such as solar, water, biogas etc. Hopefully, this house can be a self-sufficient but comfortable house for the family. Although this house is just a small example of eco-concept, zero energy homes can become a warning to remind us that we have to achieve sustainability in a global perspective as soon as possible.

References

National Climatic Center (n.d.) http://www.currentresults.com/Weather/Pennsylvania/average-yearly-precipitation.php

Solar Energy Industries Association (2014) http://www.seia.org/research-resources/solar-industry-data

Rik DeGunther (2010) http://www.dummies.com/how-to/content/the-basic-components-of-a-home-solar-power-system.html

PureEnergies (n.d.) http://pureenergies.com/us/how-solar-works/solar-panel-output/

The Eco Experts (n.d.) http://www.theecoexperts.co.uk/how-much-electricity-does-average-solar-panel-system-generate

Energy Informative (2014) http://energyinformative.org/solar-panels-cost/

Bergey Windpower (n.d.) http://bergey.com/wind-school/residential-wind-energy-systems

Picture reference, https://energypedia.info/wiki/Electricity_Generation_from_Biogas#Conversion_to_Electricity

Nathan Curry (2011) http://www.academia.edu/1196834/Biogas_prediction_and_design_of_a_food_waste_to_energy_system_for_the_urban_environment

Electrigaz (n.d.) http://www.electrigaz.com/faq_en.htm

National Climatic Center (n.d.) https://weatherspark.com/averages/30007/Harrisburg-Pennsylvania-United-States

Wind power Program (n.d.) http://www.wind-power-program.com/turbine_characteristics.htm

Curt Harting (2010) http://large.stanford.edu/courses/2010/ph240/harting2/

Solar Electricity Handbook 2015 Edition (2015) http://solarelectricityhandbook.com/solar-angle-calculator.html

PVWatts Calculators (n.d.) http://pvwatts.nrel.gov/pvwatts.php

Electric Rate - Save up to 20 percent on your electric bill. (n.d.). Retrieved March 5, 2015, from http://www.electricrate.com/residential-rates/pennsylvania/

Smart starts with Vivint Sky. ™. (n.d.). Retrieved March 5, 2015, from http://www.vivint.com/

WHERE TO BUY. (n.d.). Retrieved March 5, 2015, from http://www.lg.com/us/products/wtb?modelName=LFX31995ST

LG - Door-in-Door 29.9 Cu. Ft. 4-Door French Door Refrigerator with Thru-the-Door Ice and Water - Stainless-Steel. (n.d.). Retrieved March 5, 2015, from http://www.bestbuy.com/site/lg-door-in-door-29-9-cu-ft-4-door-french-door-refrigerator-with-thru-the-door-ice-and-water-stainless-steel/5258309.p?id=1219115991940&skuId=5258309

Rainwater Calculators - American Rainwater Catchment Systems Association. (n.d.). Retrieved March 5, 2015, from http://www.arcsa.org/?page=268

Regional Water Planning Data. (n.d.). Retrieved March 5, 2015, from http://www.twdb.texas.gov/waterplanning/data/rwp-database/index.asp

Water Tech: Home. (n.d.). Retrieved March 5, 2015, from http://www.watertech.net

How Do Reverse Osmosis Filter Systems Work & What Do They Do? (n.d.). Retrieved March 5, 2015, from http://espwaterproducts.com/about-reverse-osmosis.htm

Water System Planning-Estimating Water Needs - Water Quality (Penn State Extension). (n.d.). Retrieved March 5, 2015, from http://extension.psu.edu/natural-resources/water/drinking-water/best-practices/water-system-planning-estimating-water-use

Wastewater - Aeration. (n.d.). Retrieved March 5, 2015, from http://www.wateronline.com/solution/wastewater-aeration

Oxygen Overhaul: How to Boost Efficiency of Aeration Treatment Systems. (n.d.). Retrieved March 5, 2015, from http://www.waterworld.com/articles/print/volume-29/issue-10/editorial-features/oxygen-overhaul-how-to-boost-efficiency-of-aeration-treatment-systems.html

Charron, Rémi and Athienitis, Andreas. Design and Optimization of Net Zero Energy Solar Homes. **ASHRAE Transactions*112 (2006): 285-295.*** Print.

Kerr, Ryan Kosar, Doug. Gas Use Roadmap to Zero Energy Homes. *ASHRAE Transactions* 117 (2011): 340-347. Print.

Leidl, Chantelle M. and Lubitz David W. Comparing domestic water heating technologies. *Technology in Society* 31.3, (2009): 244–256. Print.

which.co.uk Renewable Heat Incentive (RHI) explained RHI costs and earnings." *Which*, 2015. Web. 3 Mar. 2015. <http://www.which.co.uk/energy/creating-an-energy-saving-home/guides/renewable-heat-incentive-rhi-explained/rhi-costs-and-earnings/>

Zhang, Xingxing, Zhao Xudong, Shen Jingchun, Hu Xi, Liu Xuezhi and Xu Jihuan. Design, fabrication and experimental study of a solar photovoltaic/loop-heat-pipe based heat pump system. Solar Energy 97 (2013): 551–568. Print.