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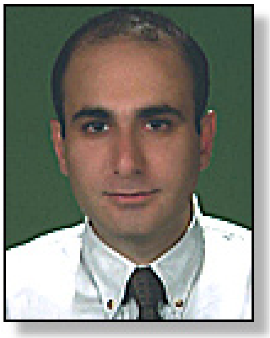

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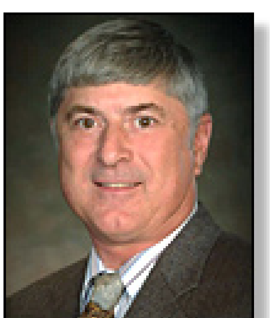

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ABSTRACT

This paper discusses innovative ways of using power through everyday activities at home. A green approach uses ambient energy sources such as solar, wind, geothermal and active/passive human power to generate electricity to power home appliances, air conditioning system, and light bulbs. The concept of a self-powered house is to use energy-efficient methods to explore ways to convert environmental sustainable energy sources into electrical energy. Sources of ambient (environmental) energy are determined prior to the design of the house in order to construct a house of maximum efficiency from ambient energy sources. Research has been conducted at several universities to make this futuristic approach for solving energy problems in the 21st century. The purpose of this research was to study a house of the future intended to be an off-grid self-sufficient, energy-efficient, and ambient-energy powered that would generate enough energy to power the appliances. This paper explains the first phase of the project which was to identify ambient energy sources and group them into specific categories such as thermoelectric, mechanical/vibrations, hydroelectric, magnetic field, airflow, acoustic noise, wind, solar/light, and geothermal. The identified ambient energy sources are characterized as high, medium, and low power sources and will also be discussed in this paper.

INTRODUCTION

As a result of greenhouse effects and the global energy crisis, discovering sources of clean, renewable energy and developing daily life applications have become critical tasks. The intent of this study is the development of a self-sufficient house emphasizing the use of modern green energy technology to decrease environmental load, accomplish energy self-sufficiency and use energy wisely in order to build a sustainable, comfortable living atmosphere. Sam Houston State University's Industrial Technology program is creating an undergraduate research program and related classes to provide students with the ability to compete in industry. Therefore, faculty must engage their students in research, especially research dealing with applied technology. There are several institutions such as the University of Virginia (UVA Solar House, 2002), Stanford University (Global Climate & Energy Project, 2008), the University of Minnesota Morris (A Green Campus, 2000), Cornell University (Renewable Energy Systems, 2009), the University of Illinois at Urbana-Champaign (The Renewable Energy Initiative, 2009), are examples of among many institutions that are involved in undergraduate renewable energy research activities.

According to the U.S. Department of Energy (DOE), renewable energy consumption was 6.260 quadrillion BTUs in 2004 and was increased to 7.301 quadrillion BTUs by 2008 in the U.S. (U.S. Energy Information Administration, 2008). In 2008, the electricity generation and flow of renewable energy was 3.88 quadrillion BTUs among all other conventional electricity generation resources. There was a considerable increase of renewable energy sources between 1949 and 2008 according to the Department of Energy statistics. The total amount of renewable energy was increased from 2974

Trillion BTUs (1949) to 7316 Trillion BTUs (2008). (Annual Energy Review, 2008). Alternative energy sources such as wind, solar, geothermal, and thermoelectric play an important role in the future of our nation. Office of Energy Efficiency and Renewable Energy (EERE) of the DOE focuses on the range of renewable energy sources by partnering with other government entities and the private sectors for providing better leverage to the federal investment in research, development, and deployment of new technologies (Renewable Energy Sources, 2008).

In 2006, about 18% of global energy consumption came from renewables, with 13% coming from traditional biomass, such as wood-burning and 3% from hydroelectricity. New renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) accounted for another 2.4% and are growing very rapidly. The share of renewables in electricity generation is 18%, with 15% of global electricity coming from hydroelectricity and 3.4% from new renewable (Global Status Report, 2007). Renewable energy in today's society provides almost 10% of the U.S. needs (U.S Energy Information Administration, 2008). In other parts of the world, governments are proactively engaged in alternative energy sources due to the global increase of fossil fuels. Renewable energy resources can be utilized in forms of radiant solar, wind, hydropower, biomass, geothermal, mechanical, and other potential sources. These energy sources provide many advantages to solving a majority of our energy problems. Some European governments offer incentives to solve environmental problems by reducing the use of conventional fossil fuel that causes green house gases, and encourage harnessing alternative energy with appropriate technology (World Resources Institute, 2009). These radical approaches to entice people to use renewable energy sources offer hope to the developing countries that are economically disadvantaged by high energy costs.

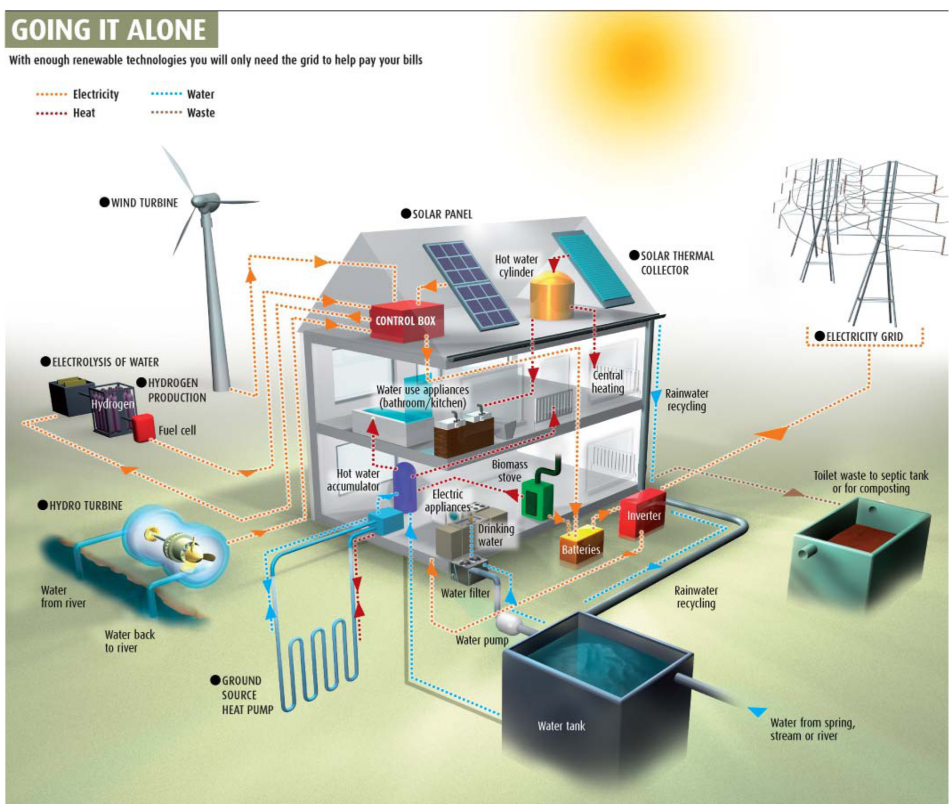
Power requirements for portable and fixed electronics systems is a growing issue in the green community. Energy storage has improved significantly, however this progress has not been able to meet the technological growth of the development of microprocessors, memory storage, and sensor applications. Ambient power sources to assist as a back-up to batteries, has come into consideration, to minimize the maintenance and replacement of storage devices. This concept can enable portable electronic devices to be completely or partially self-sufficient.

Researchers have performed extensive studies in alternative energy sources which could provide small amounts of electricity to low-power electronic devices. Energy harvesting can be obtained from different energy sources, such as vibration, light, acoustic, airflow, heat, and temperature variations. When augmented with the energy stored in common storage elements such as batteries, the environment may represent a relatively infinite source of energy. In Figure 1, potential renewable energy sources inside and outside a home are demonstrated as a reference for self-sufficient home design to generate ideas from students (*NewScientist, 2009)*. Figure 1 is a precursor to the energy related projects; the actual energy harvesting systems from renewable energy sources are identified and studied by the students in the latter half of this paper.

LITERATURE REVIEW

Since the turn of the 20th Century, scientists and inventors have pioneered technologies to harness the ambient energy that surrounds us. Nikola Tesla was one of the most distinguished scientific intellects of this period. One of his many achievements in the field of energy was an ambient energy device based on crystalline technology (Ambient Energy Developments and Applications, 2009). This unique device was the power source for an electric car. Tesla's invention trav-

Figure 1. Potential renewable energy sources for self powered house design (NewScientist,2009, http://www.newscientist.com/article/mg20026851.600-how-to-unplug-from-the-grid.html?full=true)



eled hundreds of miles through New England without gasoline. Instead of using an internal combustion engine, an AC motor was used in his electric car. Tesla also informed one of his relatives about a device that could not only supply the needs of the car forever, but also supply the needs of a house-hold with power to spare. This invention was not implemented at that time due to limited funding, difficulty in competing with more powerful energy interest groups, and the lack of manufacturing technology to process crystalline (Water Powered Car, 2009). In addition to this invention, a device that tapped energy from the meta-frequency oscillations of the vacuum of space thereby harnessing ambient energy was invented by Dr. Thomas Henry Moray in the early 1900s (Modern Energy Research Library, 2009). Gabriel Kron was one of the notable scientists who focused on negative resistors, a technology that condenses ambient energy to power a circuit without the need for another power source. He claimed that a light bulb powered by a negative resistor does not need to be powered by conventional energy sources. Floyd Sweet, a mentee of Gabriel Kron discovered that the magnetic forces of attraction and repulsion had the potential to generate electricity in a device called a, "Vacuum Triode Amplifier" or commonly called a VTA. The photovoltaic effect was first discovered in 1839 by Edmund Becquerel who was French physicist. Later on, Willoughby Smith, who was British engineer, observed light sensitivity of selenium while testing materials for underwater telegraph cables in 1873. Based on Becquerel's and Smith's findings, the first true PV cells were developed by Charles Fritts with very low efficiency in 1883. Darrly Chapin, Clavin Fuller and Gordon Pearson from Bell Laboratories used silicon instead of selenium and discovered the great efficiency of silicon cells which lead to the first useful PV cells in 1954 (Photovoltaic Systems, 2007). The ambient energy harvesting technologies developed by Tesla, Kron, Sweet, Fuller, Pearson, and Gray have all promoted the science and the practice upon which ambient energy is based upon.

The aforementioned examples provide insight for the conversion of ambient energy sources to electrical energy. Incorporating the conversion techniques may allow specific ways to fully or partially power a house or reduce the power used from the utility company. There are several self-sufficient and energy-efficient home design projects that incorporate renewable energy sources to make home design/construction a green project. An example of an ambient energy powered house design is mentioned in the Department of Energy's *Solar Decathlon* design project. The Energy Efficiency and Renewable Energy Division of the U.S. Department of Energy has been sponsoring a *Solar Decathlon* house design project competition since 2002 under the Solar Energy Technologies Program (Solar Decathlon, 2009), a program that focuses on developing cost-effective solar energy technologies that have the greatest potential to benefit the nation and the world. This project competition challenges college teams from around the globe with 10 contests to design, build, and operate the most livable, energy-efficient, and completely solar-powered house. A Solar Decathlon houses must power all of the home energy needs of a typical family using only the power of the sun. The winner of the competition is the team that best blends aesthetics and modern conveniences with maximum energy production and optimal efficiency. The latest Solar Decathlon took place in Washington, D.C. and challenged 20 student teams to design, build and operate the most attractive and energy efficient solar-powered house. First placed was awarded to Technische Universität Darmstadt from Germany, the University of Illinois at Urbana-Champaign earned second place, and Santa Clara University, California College of the Arts took third place (Solar Decathlon Final Results, 2009).

Consequently, energy harvesting (scavenging) methods should be characterized by their power density, rather than the energy density. Table 1 compares

Table 1. Comparison of power density of energy harvesting methods

Energy Source	Power Density & Performance
Acoustic Noise (Rabaey, Ammer, Da Silva Jr, Patel, & Roundy, 2000)	0.003 $\mu W/cm^3$ @ 75Db 0.96 $\mu W/cm^3$ @ 100Db
Temperature Variation (Roundy, Steingart, Fréchette, Wright, Rabaey, 2004)	10 $\mu W/cm^3$
Ambient Radio Frequency (Yeatman, 2004)	1 $\mu W/cm^2$
Ambient Light	100 mW/cm^2 (direct sun) 100 $\mu W/cm^2$ (illuminated office)
Thermoelectric (Stevens, 1999)	60 $\mu W/cm^2$
Vibration – micro generator (Mitcheson, Green, Yeatman, & Holmes, 2004)	4 $\mu W/cm^3$ (human motion—Hz) 800 $\mu W/cm^3$ (machines—kHz)
Vibrations – Piezoelectric (Roundy, Wright, & Pister, 2002)	200 $\mu W/cm^3$
Airflow (Holmes, 2004)	1 $\mu W/cm^2$
Push buttons (Paradiso, Feldmeier, 2001)	50 $\mu J/N$
Shoe Inserts (Shenck, Paradiso, 2001)	330 $\mu W/cm^2$
Hand generators (Starner, Paradiso, 2004)	30 W/kg
Heel strike (Yaglioglu, 2002; Shenck, Paradiso, 2001)	7 W/cm^2

the estimated power and challenges of various ambient energy sources (Yildiz, Zhu, Pecen & Guo, 2007). Light, for instance, can be a significant source of energy, but it is highly dependent on the application and the working environment of the device. Thermal energy, in contrast, is limited because the temperature differences around an electronic chip are typically low. Due to temperature specifications of the electronics components it is very difficult to expose electronic devices where high temperature variations exist around the device. Vibration energy is a moderate source but, like light energy, is dependent on the particular applications used (Torres & Rincon-Mora, 2005).

IMPLEMENTATION OF ENERGY SOURCES

Energy Harvesting Methods

The methods of power generation from ambient energy sources for a self-sustaining house are detailed below for each energy source.

- Solar: The use of high-efficiency solar cells/panels are used to generate electricity. Solar collectors should be used to supplement the hot water system.
- Wind: Wind generator technology is used to generate electricity.
- Human Power: Researchers have been working on many projects to generate electricity from human power such as cranking, shaking, squeezing, spinning, pushing, pumping, stepping, and pulling (Starner & Paradiso, 2004).
- Furniture (Chairs, Tables, Carpets): Design and development major students proposed new energy generating chair and table designs for active human power using crank shaft systems adapted to chairs and tables and by using piezoelectric fiber composites for carpets to generate electricity (Designboom Green Life, 2010; Pedal Powered Laptops, 2009; Energy-Harvesting Floors, 2006).
- Doors & Drawers: The motion of doors and drawers are translated to rotating motion and used to drive small generators for producing electricity.
- Floors & Stairs: Vibrations from walking on a floor are detected by piezoelectric devices and converted to electricity. Piezoelectric materials alter mechanical energy into electrical energy by straining a piezoelectric material (Sodano, Inman & Park, 2004). Strain or deformation of a piezoelectric material causes charge separation across the device, producing an electric field and consequently voltage drops proportional to the stress applied. The oscillating system is typically a cantilever beam structure with a mass at the unattached end of the lever. This structure provides higher strain for a given input force (Roundy & Wright, 2004). The voltage produced varies with time and strain, effectively producing an irregular AC signal in most cases.
- Fitness equipment: The motion of many types of exercise equipment (stationary bikes, static treadmills, stair climbers, etc.) are translated to rotating motion and used to drive generators.
- Clock mechanisms: A wind-up clock mechanism stores energy that is used to drive small generators for long durations. A pendulum clock mechanism with extra heavy weights can exert larger amounts of torque, therefore driving a larger generator used for producing electricity.
- Rainwater: Energy from guttered rain water falling through a downspout drives a small generator to produce electricity. The water is captured in a tank and used for yard watering. Water released from the tank drives a small generator to produce electricity (Rainwater Powered Energy Generating Device, 2009).
- Potable water system: Public water supplies pump water into elevated storage tanks to maintain positive pressure on the public water system. A positive displacement, rotary vein type drive device, attached to a generator, is placed in the main supply line to the house. As water is consumed in the house, the flow of water causes the device to produce electricity. Likewise, similar devices are attached to the supply lines of various water consuming devices (toilets, lavatories, sinks, showers, tubs, washing machines, etc.) in the house to generate electricity.
- Gray water system: Devices similar to those used in producing electricity from guttered rainwater can be applied to the gray water systems going from the house (lavatories, sinks, and washing machines, etc.) and likewise can be converted into electricity.
- Thermoelectric generation: The heat from a roof is used to affect thermoelectric devices and materials to generate electricity. Thermoelectric generators are used to convert differential water temperatures between solar-heated water and tap water into electricity. Thermal gradients in the environment are directly converted to electrical energy through the Seebeck (thermoelectric) effect as reported by Disalvo (1999) and Rowe (1999).

Energy Conservation Methods

In our national debate about energy independence, fossil-fuel alternatives get most of the attention. Meanwhile, energy conservation efforts are getting some attention but not as much as alternative energy sources. Conservation may not be as exciting as hydrogen cars or windmills, but it can offer immediate relief from our increasing energy costs and reduce our consumption of fossil fuels. There are many possible ways to conserve energy. These methods are usually applied during the construction of the buildings and summarized as follows:

- Windows: The use of liquid crystal technology to filter light coming though window glass reduces solar heating within the house thereby reducing cooling energy needs. Low emissive ("Low E") glass coatings reduce ultraviolet rays entering the structure and reduce home HVAC (heating, ventilating, and air conditioning) system energy requirements.

- Insulated Concrete Forms (ICFs): ICFs for wall systems offer greater "R" values and reduce heat loss or gain within the structure, thereby saving air conditioning energy requirements.
- Structural Insulated Panels (SIPs): Like insulated concrete forms, SIPs offer greater "R" values for wall and roof system reducing heat loss or gain within the structure but at a lower material cost than ICFs.
- Light Emitting Diodes (LEDs): LEDs are low power electric lighting devices that have a long life expectancy. Use of LED lighting reduces the amount of electric power conventionally needed for a house. LEDs have been implemented to light structures and have proven to be more efficient than incandescent or even fluorescent bulbs in a watt per lumen ratio.
- Solar Lighting: During daytime hours, solar lighting using skylights and light pipes reduce the need for conventional electric lighting.
- Rainwater collection: Rainwater is collected for future non-potable uses such as yard watering.

Figure 2(a). Overall energy harvesting simulation interface of PFCB using AMESim

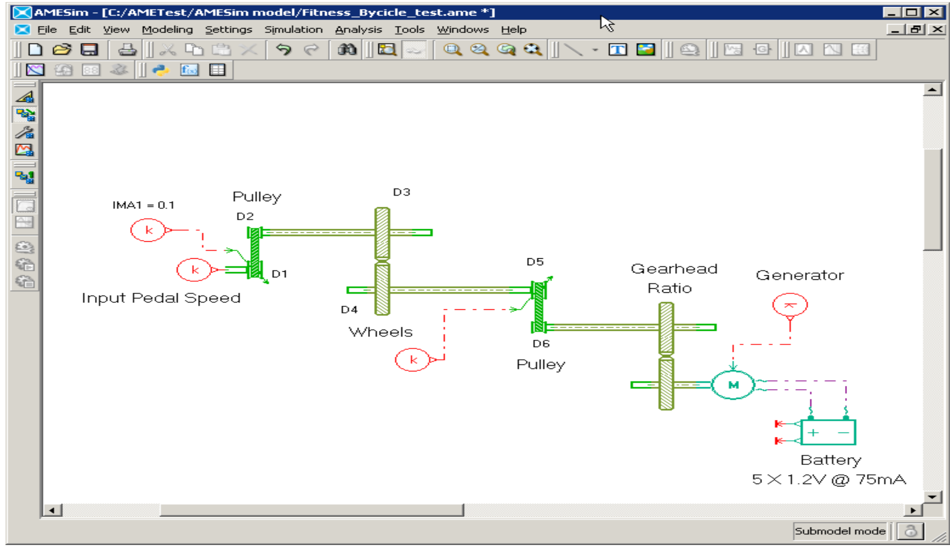
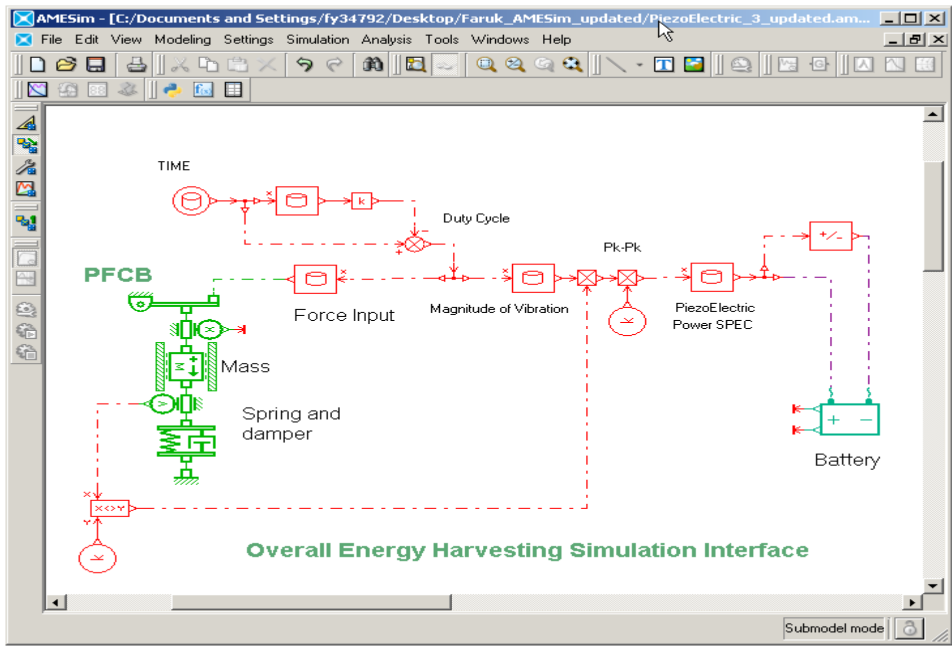


Figure 2(b). AMESim energy harvesting simulation interface (exercise bicycle)



STUDENT INVOLVEMENT

Students involved with this research were able to experience undergraduate research, engage in creative thinking and problem-solving activities, and participate in hands-on experiences that will benefit their future careers and further their current knowledge of alternative ambient energy sources. A variety of software simulation tools were used in this research. LMS AMESim, which is a one dimensional analytical simulation software (LMS Imagine.Lab AMESim Suite, 2009) and NI Multisim which is an electronics circuit design and simulation software (What is NI Multisim, 2009) etc. were used to investigate the viability of the systems prior to actual implementation. Two design and simulation examples were created using LMS AMESim and are depicted in Figure 2. The first system (a) was an exercise bicycle energy harvesting system designed, analyzed, and simulated with real specifications of the overall components that included the wheel ratios, generator, circuit, and battery unit. System (b) was an energy harvesting system from a shoe soles using a piezoelectric material (PFCB –Piezoelectric Fiber Composite Bimorph). After investigation of characteristics of both systems, the engineering design and simulation of the overall systems were modeled using LMS AMESim with real specifications of all the components. Each source of ambient energy was assigned to a student or student group according to their major/minor or individual interest. Assuming energy-friendly products consume less energy, computer models of energy-friendly home appliances may be developed by the design and development major students using Computer Aided Design software tools such as AutoCAD, PTC

Pro Engineer, and AutoDesk Inventor. This study gathered students from a variety of disciplines to conduct this research. The project engaged student participation from different disciplines (construction management, design and development, industrial technology, and electronics).

CIRCUIT DESIGN

Since harvested energy manifests itself in irregular, random, low/medium-energy bursts, a power-efficient, discontinuous, intermittent energy harvesting and regulation circuit would be required to transfer the energy from the ambient energy source to the storage unit. All the components of the circuit might be carefully selected to avoid major losses through the circuit; and the circuit needs to be protected from unexpected shorts and high voltages from the stray energy sources. Furthermore, a universal design for the energy harvesting circuits should be flexible enough to allow for the adjustment of charging voltage/current to accommodate different capacity storage devices. Typical energy harvesting circuits need to be designed, developed, and implemented for the purpose of low/medium power ambient energy harvesting. Circuit design for energy harvesting for low power sources is intended to accommodate all types of low power sources. Designing unique circuits for each ambient energy source is time and cost prohibitive. Prior to the implementation of test circuits energy harvesting circuits can be developed using a variety of circuit simulation program tools such as National Instruments' Multisim, and Linear Technology based LTspice SwitcherCAD III (LTspice, 2009).

POTENTIAL AMBIENT ENERGY SOURCES

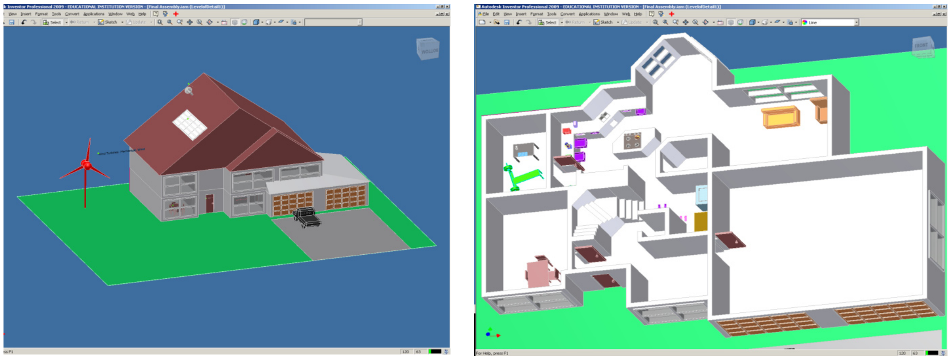
The ambient energy collected from different sources is characterized as high, medium, and low power sources. Energy generation from solar, wind, and hydroelectric power sources is considered a high power source. Energy from pedaled chairs (new design) and tables (new design), fitness equipment, collected gray water (from sinks, bath and rain), city water, and some furniture is considered to be a medium power source. Power from opening and closing of doors and cabinet drawers, floor vibrations, clocks, and heat differences etc. is considered to be a low power source. All energy collected from aforementioned sources must be converted to electrical energy and transferred into storage devices (batteries or super/ultra capacitors) using energy harvesting, regulation circuits.

Energy sources listed in the follow-

Table 2. Potential Energy Sources

Thermoelectric (Heat differences, temperature variations) 1. Fireplace 2. Range 3. Oven 4. Vehicle Exhaust 5. Clothes dryer 6. Roofing material 7. Toaster 8. Dish washer 9. Refrigerator 10. Kettle 11. Bread maker 12. Cooking air filter 13. Coffee maker 14. Microwave 15. Hair dryer 16. Body temperature 17. Walls	**Mechanical & Waste Vibrations** 1. Fitness equipment 2. Chairs, Tables (New design - crankable) 3. Sewing machine 4. Rain water 5. Roof vents 6. Mixer 7. Blender 8. Waste disposer 9. Refrigerator 10. Bread maker 11. Cooking air filter 12. Fan 13. Cabinet drawers 14. Sneakers/sleepers/shoes (insole/sole) 15. Stairs/stairways 16. Doors 17. Couch and sofa 18. Bed 19. Floor 20. Keyboard 21. Mouse
Hydroelectric (Gray water system, potable water, rain water, water pressure from utility company) 1. Bath/shower 2. Rain water 3. Sink 4. Gray water drains 5. Dish washer 6. Washing machine 7. Faucet, Lavatory 8. Toilet reservoir	**Magnetic Field** 1. Cloth dryer 2. Dish washer 3. Washing machine 4. Waste disposer 5. Cooking air filter 6. Keyboard
Airflow 1. AC Unit fans 2. Roof vents 3. Clothes dryer 4. Fan 5. Hair dryer	**Acoustic Noise** (Sound Incidents) 1. TV 2. Radio 3.. Noise (Human, pets, vehicles)
Wind 1. Wind turbines 2. Vehicle (Equipped with small turbines)	**Solar/light** 1. Solar 2. Vehicle (Equipped with PV cells) 3. Internal lightening
Geothermal • Geothermal energy systems	

Figure 3. The model house



ing table show where potential ambient energy exists and can be captured. Some of the sources (such as solar, wind etc.) have already been investigated and energy is being converted and used in most of those locations. The sources listed in the Table 2 were identified by the students during the regular brainstorming meeting sessions. The viability of the sources was discussed among the students under the supervision of the instructor. After investigations of sources, a survey was given to five different classes to rank sources depending on their energy generation capabilities. The sources in the survey were explained again individually to give an idea of how to generate power from that source to students. Total fifty eight students were participated survey. Sources in the table were ranked from first to last according to student rankings evaluated using Microsoft Excel 2007.

The model house was designed by the design development students using Autodesk Inventor including energy harvesting sources indicated in Figure 3. Also, a small scale storage house was built by construction technology students to study the viability of each source. The detailed section views of the listed sources are not provided in Figure 3 (Inventor screen shots). Figure 3 is an Inventor assembly consisting of many individual parts designed and assembled to create an assembly. Individual parts were designed by design and development major/minor students and assembled by a senior level student using Autodesk Inventor. The size of the designed house is 65’ X 45’ft. Each component of the house was designated with real dimensions obtained by students in Computer Aided Drafting Productivity class as a class project. Each student in the class, created each component of the house as assigned by the course instructor. Each component was considered as a potential energy generation unit as required in project proposal. For example, a couch was designed to generate electricity with two different ways. First way was pedaling system that is pedaled by a person while sitting on the couch. The captured rotational mechanic energy is captured by a generator. Second way was vibration energy conversion (piezoelectric effect) by turning and moving of a person on the couch while sitting. Deformations and shakings from a couch are captured with the movement of a person.

BENEFITS FOR RESEARCH

Ambient energy sources (small scale and decentralized renewable energy sources in particular) will let individuals and communities create and consume energy locally. The promotion of renewable energy sources by home owners has brought a particular focus to the passive and active use of natural energy sources. Through the combination of natural energy, energy conservation, and better insulation, residents will enjoy greater comfort with less energy use.

Undergraduate students benefitted from this research project experience by learning cutting-edge techniques to create alternative energies. The house design provides contextual learning and hands-on approaches in conducting research. In addition, faculty can experience an *outside classroom* with real-life problem-solving techniques which can greatly add to the value of their program’s graduates.

CONCLUSION

This experimental research study incorporates different disciplines to gather data on both energy reductions within the household by incorporating energy-friendly devices and generating energy from ambient energy sources. Such research is needed to increase the use of ambient energy sources by providing detailed information to the public about the reliability of the sources. The students have defined the potential ambient energy sources available during regularly scheduled meetings. Email distribution lists/groups are used to communicate with students according to their interest groups and to track the amount of work accomplished at the time of the email communication. A small wood frame structure was constructed using conventional construction techniques and materials to investigate the resources in detail. This allows exploration and experimentation with the integration of potential energy harvesting and energy conservation techniques used for final design considerations. Also, a new renewable energy class (energy harvesting systems from alternative energy sources) was developed for the Industrial Technology program. Most of the research projects described in this article are good reference material for students enrolling in the Renewable Energy course offered as elective in the Industrial Technology program curriculum. Most of the research projects discussed in this paper are demonstrated to students in the Energy course and students are required to extend and improve the projects throughout the semester. The identified sources will lead to further research to design and build actual houses to test all the sources proposed in this study.

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