AC 2012-3200: INTEGRATION OF APPROPRIATE TECHNOLOGY INTO AN ALTERNATIVE ENERGY CLASS

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Integration of Appropriate Technology into an Alternative Energy Class

Introduction

For eleven years the Department of Mechanical Engineering at Michigan State University has taught a project based alternative energy course. The focus of the course is for students to use their background in thermodynamics, fluid mechanics, heat transfer, and electronics to perform predictive calculations for various alternative energy technologies. The concluding assignment for the course has asked students to prepare a one page white paper recommending the implementation of an alternative energy technology and make a one minute presentation using one overhead. The intended audience is the Secretary of Energy. Recently, there has been significant interest in appropriate technology as seen in the increased activity of Engineers Without Borders [1] on college campuses and the establishment of Engineering for Change (E4C) [2]. Appropriate technology is technology for energy, water, and health that departs from the conventional western technology and is focused on the appropriate use of a developing country's resources, so as to not disrupt its culture and environment. In the last offering of our alternative energy course, we replaced the previous final assignment with one that has an appropriate technology focus. The students were asked to prepare a one page white paper recommending the implementation of an appropriate energy technology and make a one minute presentation for the Director-General of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

This paper presents the background material on appropriate technology that was provided to the students, including an appropriate technology checklist. Some of the more interesting white paper topics are presented. An evaluation of the white papers is included and student feedback is provided. The paper concludes with lessons learned.

Background

Recently the term Appropriate Technology has become prevalent in the efforts that the developed world is taking to assist developing countries. The term applies to technology for energy, water, agriculture, and health that departs from the conventional western technology and is focused on the appropriate use of a developing country's resources, so as to not disrupt its culture and environment. Further, the technology should be simple and inexpensive to employ and could lead to the development of cottage industries. For most of us that have been involved in bringing alternative energy technologies to the developing world the concept of appropriate technology brings a paradigm shift. No longer should we think about coming into a village installing a $100,000 solar photovoltaic pumping system and then walk away very pleased with ourselves. In addition to maintenance and upkeep issues, for the one village that is helped there are millions of villages left to struggle with their water supply.

Basic Principles

In general the world can be divided into developing countries, emerging countries, and developed countries. We begin by considering what we mean by a developing country. As it turns out, in some circles this is a very controversial term. The United Nations does not use this designation. The World Bank defines it on the basis of per capita gross national income (GNI). They define a developing country as one having a per capita GNI of less than $4000 ($4,000 per

person per year). The International Monetary Fund (IMF) uses an indexing system that includes per capita GNI, export diversification, and degree of integration into the global financial system. Another definition is based on the United Nations Human Development Index, which includes such factors as: life expectancy at birth, adult literacy rate, the combined primary, secondary, and tertiary gross enrollment ratio, and gross domestic product per capita at purchasing power parity. An HDI score above 0.788 is often used to identify the developed countries of the world. Perhaps the best definition is the one provided by Kofi Annan, former UN Secretary General:

> "A developed country is one that allows all its citizens to enjoy a free and healthy life in a safe environment."

Using these definitions, let see what we can identify as developing countries:

Most of Africa
Indian Subcontinent
Most of Latin America
Southeast Asia
Eastern Europe (probably emerging)
China (probably emerging)

A list of appropriate technology characteristics has been developed and is shown in Table 1. It is suggested that about ¾ of this checklist should be satisfied for a technology to be considered an Appropriate Technology.

Table 1 Appropriate Technology Characteristics

Addresses a need of the people in a developing country.
Promotes "a free and healthy life in a safe environment"
Socially and culturally acceptable
Raw materials availability
Labor (including skilled) availability
Can be made, maintained, and repaired in country
Has a reasonable cost and price relative to the country
Is attractive to the end user (by their definition)
Can lead to a cottage industry
Is a viable replacement for the current approach
Is sustainable
Does not harm the environment
Microfinancing could be used to develop the business

The Assignment

As the final assignment for the alternative energy class (the students will have already conducted four design projects on various alternative energies as described in [3]), the students were asked to prepare a one page white paper recommending the implementation of an appropriate energy technology and to make a one minute presentation for the Director-General of the United Nations Educational, Scientific and Cultural Organization (UNESCO). The actual assignment is

provided in Figure 1. Clearly, this is a very open ended assignment, allowing the students to pursue any interest they might have. They were made aware of the web sites for Engineers Without Borders and Engineering for Change (E4C), which they could use to give them some ideas for potential technologies.

Approximately 3 lecture periods were devoted to the concepts of appropriate technology. These lectures focused on the nature of appropriate technology and its characteristics (per Table 1). Two alternative energy projects that were MSU Engineering Capstone Design Projects were presented to the students and were critiqued in the terms of satisfying the appropriate technology checklist. The two projects are described below. Following class discussion, the students came to the conclusion that the Connect-On-Demand Satellite Link was not an appropriate technology, while the Vaccine Refrigerator did satisfy the criteria for an appropriate technology.

Connect-On-Demand Satellite Link for Tanzanian Schools

The team has been challenged to design a solar-powered, "connecton-demand" satellite/radio link. With this new design in place, the system will draw minimum power from the batteries while optimizing the time of its usage. This will allow the Tanzanian users to gain the most out of their internet while staying well within their power limitations. In essence, the students at any of the three schools will be able to connect to the internet at any time, causing it to power up when accessed. Currently, the initial set up of this system is implemented such that only Baraka has control over the satellite antenna, which sometimes limits the availability of the internet for users at Manyara Secondary School. We will eliminate that limitation and extend similar capabilities to Rift Valley Secondary School.

A Vaccine Refrigerator for Remote Regions

Many of the vaccines used to control diseases require cold temperatures for preservation. Without a reliable power infrastructure, developing countries often lack the resources to keep these vaccines cool for an extended time period, hampering the ability to adequately protect citizens. It is estimated that 50 percent of vaccines in rural areas are wasted due to spoilage. To address this problem, a capstone design team developed an affordable, robust refrigerator that operates with energy from the sun. The vaccine refrigerator was designed with simplicity as a focus for manufacturing, maintenance and daily use. It uses widely-available alcohol as a refrigerant and has no moving parts. Manufacturing can be completed with common materials and simple assembly techniques. After the initial vacuum charging, the refrigerator is designed to work without maintenance for three to five years.

Figure 1 Appropriate Technology Class Assignment

ME 417
Design of Alternative Energy Systems

Policy Recommendation
Due Wednesday, May 4 at 7:45 a.m.

As part of its commitment to public service the engineering firm of Bénard and Somerton (aka BS Engineering) has assigned one of its associates (you) to serve as a pro bono advisor to Director-General of the United Nations Educational, Scientific and Cultural Organization (UNESCO) on appropriate energy technology issues. In this role, you have been asked to prepare a one page white paper recommending the implementation of an appropriate energy technology and make a one minute presentation using one overhead. The white paper should be a persuasive essay with a combination of sound bites and technical/economic arguments. The one minute presentation will be made at the final exam period for the course and the student should be prepared to field questions during a 1 minute question/answer period. The overhead used for the presentation should be a transparency used for overhead projectors and it is strongly recommended that it not be just a copy of the white paper but that a bullet format should be used. The attached grading sheet will be used to assess the policy recommendation.

A list of the technologies proposed by the students is shown in Table 2. Unfortunately, several of them are not appropriate technologies. By the instructor's assessment the technologies were identified as follows:

Appropriate Technology: 26
Some Components of Appropriate Technology: 10
Not Appropriate Technology: 13

It is of interest to note that 8 projects focused on water purification, indicating that the students realize how important the water issue is in the developing world.

Table 2 Appropriate Technology Proposals

Low Cost Water Generators using Bamboo and Automotive Alternators
Solar Cooker/Solar Water Heater
Earthly Water Filter
Attachable Solar Reflector
Ocean Thermal Energy Conversion
Hand/Foot Powered Electric Generator
Solar Powered Air Conditioner
Hydraulic Ram Pump
LifeStraw Personal Water Filtration Device
Animal Power Water Pump
Solar Chimney
Water Powered Battery Charger
Wind Powered Electric Generators for Developing Nations
Feces Powered Energy
Personal Wind Turbines
Human Powered Bicycle Generator
Solar Hydrogen Generation System
Pot-in-Pot Refrigeration
Kinetic Energy Powered Emergency Charger
Ceramic Water Filtration Using Solar Ovens
Solar Lighting
Solar Powered Automatic Window Blinds
Solar Dehydration System for Food Preservation
Advancement to Solar Water Purification through use of Solar Oven
Solar Water Heater
Bicycle-Powered Electric Generators
Wind Belt Power Source
Solar Powered Water Irrigation and Supply System
Magmus Effect Airborne Wind Turbine
Vortex Induced Vibrations for Aquatic Clean Energy
Biogester
Solar Powered Light Bulbs
Wave and Tidal Energy using BioWave System
Ceramic Water Filters
Solar Photovoltaic Powered Electronic/Digital Stethoscope
Household-size Continuous Rice Husk Gas Stove
Kinetic Energy Adapters for Gym Equipment and Bikes
Non-invertive Feedback Thermofluidic Engineer
Solar Powered Refrigerator
Induction Kinetic Energy-Electrical Generator
Rocket Stoves
Solar Power Bike Pump

Table 2 Appropriate Technology Proposals (continued)

Rooftop Rainwater Collection and Purification
Solar Powered Light Bulb
Enhanced Geothermal Systems
Pot-in-Pot Evaporative Refrigeration System
Solar Photovoltaic Systems for Rural Areas
Solar Disinfection of Water
Biomass Burning Cook Stove
Solar Power Water Purification
Biomass Gasifier

Three of the more interesting proposal are shown in Figs. 2-4. The students were provided with a grading rubric, which is shown in Fig. 5.

Figure 2 Example of Student Work

ME 417 Design of Alternative Energy Systems

TO: Professor Craig W. Somerton

FROM:

DATE: May 4, 2011

SUBJECT: Low Cost Water Generators using Bamboo and Automotive Alternators

There is an energy source that remains untapped in many developing countries: small rivers and waterfalls. The energy of the moving water can be extracted using low cost water generators that can power basic devices like water pumps. In addition, the generator can be made using low-cost materials available in most places. Developing this technology can lead to a simple, inexpensive, and sustainable energy source for places with nearby moving water, such as mountainous areas and the Amazon.

The generator consists of two lightweight disks rotating on a simple spindle with halved bamboo pieces connecting the disks. A common automotive alternator, attached to the disk, generates electrical power as the turbine rotates. Another option is an automotive electric fan motor. The choice between the two depends on the expected velocity of the turbine (based on the water source) since an electric fan motor operates at lower RPMs but produces less power. Clearly, materials for this device are basic and easy to obtain. This technology is not new and vast amounts of research and knowledge are available to optimize a turbine design that can work in a multitude of locations around the world.

Finally, a small industry could develop from creating these low cost systems. Labor is minimally complex and can be performed in most places. Overall investment is very small, so microfinancing could be used to expand this solution to a global water crisis.

Figure 3 Example of Student Work

BS Engineering

To: Irina Bokova, Director General
United Nations Educational, Scientific and Cultural Organization

From: Senior Partner
Benard and Somerton Engineering

Date: May 04, 2011

Subject: Wind Belt Power Source

The need for off the grid power in rural parts of third world countries continues to increase in demand. With an increase in the amount of battery operated devices being used and the need to charge them, as well as the need to power lights and items like radios and clocks, a promising alternative energy application needs to be determined. Currently in rural parts of Haiti, homes use a small kerosene generator to create enough electricity to power a few lights and necessary devices. This is costly for a family that may only bring in $2 to $4 a day, and kerosene is a pollutant and a fire hazard. Another approach that is currently in use is individual household solar panels. These panels work, but are expensive and delicate. To solve this problem, one inventor, Shawn Fraye, has developed a simple mechanism that is cheap, repairable and effective.

The device is called a *Windbelt*. It is a simple sturdy frame with a high tensile ribbon running through the center. On one end of the ribbon is a metal button, and on both sides of the frame surrounding the metal button are electric coils. The device works by using wind energy that passes through the frame and causes the effect of aeroelastic flutter on the ribbon. This flutter is a vibration that moves the metal button back and fourth creating electricity through electromagnetic induction.

The device is scalable and currently comes in a few different sizes. For the application of generating electricity in the third world, a one-meter *Windbelt* would be optimal. It is also modular and capable of being combined together to produce a higher electrical output. For a one-meter belt, the projected electrical output is around 1kWh per month at a cost of $0.05/kWh at an average wind speed of 6 mph. For an application of powering a few lights, and charging some batteries, this is more than sufficient and incredibly affordable, and also provides excess power to be used for additional tasks.

One of the greatest benefits of the *Windbelt* is that it has few parts, and is producible and repairable by citizens of the country of operation. The device is also very adaptable, and the frame and ribbon can be made from almost any available material that meets the needs of the device, which is a sturdy material for the frame, and a strong ribbon like material for the belt. With a little instruction and training, the device can be implemented and start reducing the environmental impact of hydrocarbons, and provide necessary electricity for parts of the world that are in need.

Figure 4 Example of Student Work

BS ENGINEERING

To: Irina Bokova, Director General
United Nations, Educational, Scientific, and Cultural Organization

From:
BS Engineering Associate

Date: May 4, 2011

Subject: Rooftop Rainwater Collection and Purification

The United Nations has acknowledged that approximately 2.6 billion people lack access to safe drinking water and sanitation. The annual death toll attributed to water sanitation related diseases is estimated to be 1.6 million people. Those with limited access are typically unable to improve their circumstances because most time is spent retrieving water or suffering from illnesses rather than attending school or working.

In order to promote a healthier standard of living, a rainwater collection and purification system is proposed for implementation in approved locations. The initial concept utilizes an open capture tank on a rooftop for rainwater collection. The collector is filled with sand and slanted to the rooftop edge where a pipe drains the filtered water to a second collector just above ground level. At this point a solar reflector is focused on the second collector containing the once filtered rainwater in order to boil the water and kill hazardous micro-organisms. A recycle loop is incorporated into the ground collector attached to a second solar reflector to continually loop and re-sanitize the collected water. The water will evaporate and flow into the collector tank where it will re-condense; the evaporated water will continually replenished with the cool water supply from the tank. The system can be scaled to fit the needs of the application, like a school or individual house. If the application allows, a solar powered pump could provide sufficient pressure within the building's pipelines to supply running water.

While the system has multiple components, the concept was generated to utilize materials and manufacturing processes that could be purchased locally and inexpensively as opposed to an imported material or skill set. Other than the need for a reflective material for the solar collector, any material that can structurally withstand expected stresses and provide desired flow rates is adequate for this concept. Maintenance and periodic cleaning of the system will be required, but can users can be easily trained without any need for a technical background. Support and education of the system will be necessary to encourage cultural acceptance of a new system and water taste; however, most residents will be familiar with boiling water, making the water purifier less intimidating.

Initial funding may be required to fund initial costs; the water purification system will not directly pay for itself through sale of goods, but eventually will improve economic potential through increases in worker productivity and decreases in healthcare costs.

Figure 5 Grading Rubric for Appropriate Technology Assignment

ME 417

Design of Alternative Energy Systems

Grade Evaluation
Policy Recommendation

Student: _____

Topic	Assigned Score	Maximum Score
Innovation		2
Technical/Economic Content		3
Socio-Political Content		2
Presentation		2
Questions		1
Total		10

Student Grading and Feedback

The grade distribution for the assignment is shown in Fig. 6. The average score was 8.5 and the median score was 9. The low scores were mostly due to the fact that the proposal did not deal with an appropriate technology. All in all, the students performed well on the assignment.

As part of the end-of-semester course survey, three questions were asked concerning the students' learning experience on appropriate technology. Those questions and the average responses are shown in Table 3. The students were asked to use the University's grading system (4.0-0.0) in their responses.

Figure 6 Grade Distribution for Assignment

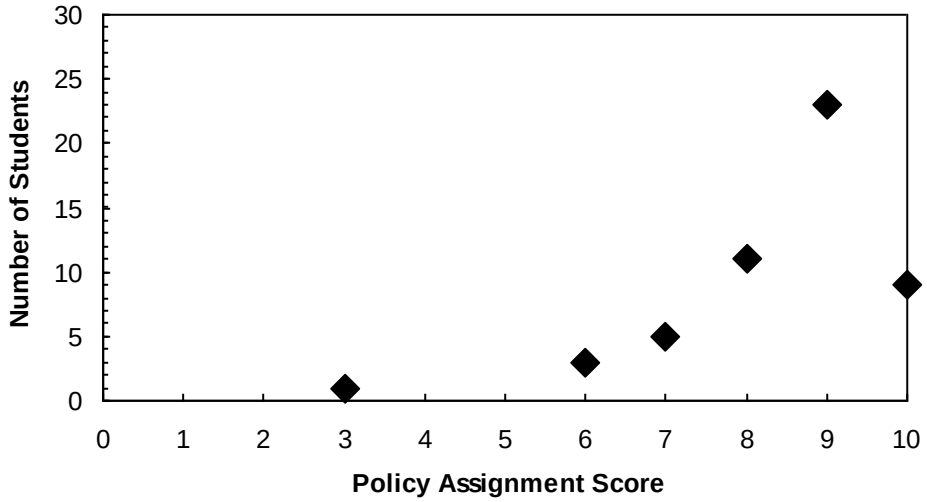

Table 3 Survey Results

Survey Question	Average Response
You are able to understand the nature of appropriate technology.	3.88
You can identify what is an appropriate technology.	3.94
You are able to understand the connection between appropriate technology and the developing world.	4.00

Lessons Learned

- It seems appropriate to introduce the concepts of appropriate technology to an alternative energy class, though some students showed resistance to thinking globally about these issues.
- Several students still struggled with the concept of what is appropriate technology. Perhaps the students should submit a pre-proposal, say a one paragraph describing the technology, and use the appropriate technology check list to evaluate their idea.
- Several students wanted to have the opportunity to build and test their ideas. This might be possible by incorporating this assignment in a humanitarian engineering course.

References

1. Engineers Without Borders – USA, http://www.ewb-usa.org/, visited 3/18/12.
2. Engineering for Change, https://www.engineeringforchange.org/home, visited 3/18/12.
3. Somerton, Craig and Bénard, Andre, "Developing a Design Based Alternative Energy Course", Processing of the 2005 ASEE Annual Conference, June 2005.