AC 2007-1614: A DELPHI STUDY TO PROJECT THE FUTURE OF ALTERNATIVE ENERGY AND ITS IMPLICATION TO ENGINEERING TECHNOLOGY

David Rouch, Ohio Northern University

David Rouch is Professor and Chairperson of the Department of Technological Studies at Ohio Northern University. He received his Bachelor's degree from Ball State University, M.S. from Eastern Illinois University, and PhD from The Ohio State University. He teaches courses in Energy and Transportation and CAD/Design.

Adam Stienecker, Ohio Northern University

Adam Stienecker teaches electronics and applied control systems courses at Ohio Northern University in the Department of Technological Studies. He holds undergraduate and doctorate degrees in Electrical Engineering from the University of Toledo in Ohio. His areas of research include alternative energy and alternative energy storage devices.

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Abstract

The future of energy supplies in our world is largely in question. It is widely accepted that the world's inhabitants cannot continue to depend on traditional, non-renewable, fuels as they harm the environment and are in limited supply. Researchers and research organizations worldwide have committed themselves to the research and development of alternative energies and its storage and must put out a similar effort to educate the general public and future energy users and decision makers in the alternative energies being developed. This paper reports the findings of a Delphi study conducted by the authors to determine what components should be included in the curriculum of an alternative energy program and also find out what emerging technologies are likely to have the most impact over the next 5-20 years. According to the Delphi panel of experts, most of the obstacles to alternative energy development are more political in nature than technical.

Introduction

Alternative Energies has again come to the forefront as part of curriculum reform at all levels, K-16. The impetus for this renewed interest has been the political situation in the Middle East, the rising cost of energy, limited fossil fuel supplies, and the concern for an increasing amount of CO_2 in the atmosphere that some believe is causing global warming. The renewed interest has brought about the need to be proactive in developing programs that will be responsive to supplying the needs for workers with the technical competence and "know-how" to design, build, install, inspect, service, troubleshoot, maintain, manage, and in general, be good consumers of the alternative energy technologies being developed. This study utilized a Delphi approach to develop a consensus of what experts in the field of alternative energies believe should be critical components of a program preparing individuals with a high level of competence in the field.

Methodology

The Delphi technique was utilized because it pools the knowledge of experts within a defined field to build a consensus to forecast what is likely to occur in the years ahead. Such projections are very accurate because it is utilizing the knowledge of those who are at the cutting edge of research and study in a particular field and are therefore very much in touch with what the issues and trends are in a field. The Delphi method has been very useful to other curricular areas to pool expert knowledge for planning for future trends [5], [6], [7]. A panel of experts was identified for participation in the study that included individuals with expertise in the major areas comprising the alternative energy field so that a balanced perspective would be developed in the consensus building process.

The first round of the Delphi study started with an open ended questionnaire mailed via email asking the panel of experts to respond to three general questions as follows:

1. What major areas constitute the areas that need to be considered relative to educating students about Alternative energies?
2. What alternative energy technological developments and implementations are likely to occur in the next 5, 10, 15, and 20 years?
3. What major obstacles or problems are holding up the development and implementation of the alternative energies listed in question #2?

Known areas such as photovoltaics and wind were provided as a basis for question one in order to allow the panel to focus on the areas that required their input. However, the experts were encouraged to provide answers not included and those results were added. All results given in questions two and three were provided solely by the experts.

The results from the panel of experts were analyzed and compiled to produce the 2nd round of the Delphi Study. The 2nd round used an online survey instrument (http://www.surveymonkey.com/) to simplify the data collection process and lessen the burden placed on the panel of experts for responding to the questionnaire. The researchers then compiled the results of the 2nd round and present them in the following section of this paper.

Results

Categories for Alternative Energy -There are several useful findings from the study. At first, it was determined by the researchers that the main areas to focus the instruction around was Alternative Energy Sources and Alternative Energy Storage. The panel of experts added to this area the need to also focus on the reduction of demand on these two areas of alternative energy by designing things with energy efficiency in mind. The sub-areas identified are listed along with the percent of consensus among the panel of experts in the table below:

Alternative Energy Sources	Consensus
Wind	100%
Solar (Photovoltaic)	100%
Energy transformation devices (hybrids, sterling engines, motors, generators, etc.)	100%
Solar (thermal panel heating)	80%
Solar-thermal electric	80%
Concentrating solar power (CSP)	80%
Geothermal	80%
Bio-fuels	100%
Micro-turbines	80%

Alternative Energy Storage	Consensus
Fuel Cells	100%
Advanced Batteries	100%
Ultracapacitors	100%
Pumped Storage Hydro-Electric	80%
Flywheels	100%

Energy Efficiency Issues	Consensus
Energy auditing (commercial, residential, industrial, transportation)	100%
Waste reduction	100%

Systems/wholistic thinking	80%
Policy making	80%
Sustainable/Green Building Construction Methods	100%
Power grid transmission and distribution capabilities and improvements	100%

Forecast of Technological Developments-The second major research question was to ask the panel of experts when certain developments were expected to occur. Knowledge of pending developments gives educational decision makers a "window into the future" so they are able to be more proactive in developing programs as they are needed rather than in a delayed "reactive mode." The table below presents the projections made by the panel of experts regarding alternative energy and the percent of consensus that was garnered. In some areas, there was more support for moving the development/forecasted projection to later years of development than keeping them in the category specified, so they are marked as such.

In the next 5 years:	**Consensus**
Significant (majority of) public buy-in that there is really a global warming problem	75%
More public awareness of and taking action on energy conservation options	75%
More applications for LED type lighting	100%
More energy conservation product and facilities being brought on line.	100%
Higher performance lower maintenance wind turbines for land-based use	75%
The use of geothermal heating and cooling systems for commercial and residential buildings.	75%
Affordable small-scale wind turbines, solar photovoltaic and microturbines (CHP) systems for residential use.	75%
Rooftop solar thermal will be used in 5% of the new homes built	Later
Wind power will have significant increased use with 5 year pay back period	Later
Photovoltaics will be cost effective to have a 5 year pay back period	Later
Concentrating solar power will be used for heating homes	Later
Development of advanced Li-ion batteries and the cost reduction on Ultracapacitors and other current energy storage technologies.	Later
A demise of the ethanol fuel approach to renewable energy.	Later

In the next 10 years:	**Consensus**
Significant break through in battery technology via new materials and mfg. processes	50%
Cost-effective offshore wind technology for U.S. coastal regions	100%
Solar-thermal electric systems for the desert U.S. Southwest	25%
Advanced batteries will be used in the passenger vehicles.	50%
Ultracaps will be used on electric vehicles by a major automotive manufacturer	50%
Significant infrastructure development for alternative fuels distribution	Later
Rooftop solar thermal will be used in 1% of the new homes built	Later
Wind turbines will provide 20%+ of all U.S. electric needs (compared to less than 1% today.)	Later
All new buildings built, regardless of local climate, will operate on just 25% of the fossil fuels used today.	Later
Fuel cells will be used on production vehicles by a major automotive manufacturer	Later
Fossil fuel supply throughout the world will be depleted making alternative fuel supplies more cost effective	Later

In the next 15 years:	**Consensus**

Smart, integrated electric power networks, with intelligent use of distributed storage and generation will be in use.	75%
There will be cost-effective building integrated solar Photovoltaic systems, aided by the smart power network.	50%
Fuel cells will be used on production vehicles by a major automotive manufacturer	25%
Ultracaps will be used on electric vehicles by a major automotive manufacturer	25%
Development/cost reduction of Fuel cells and implementation in mobile applications	Later
The U.S. becomes self-sustaining, providing 75% of its energy needs from renewables.	Later
Efficient long distance power transmission--to facilitate wind and concentrated solar power	Later
Rooftop solar thermal will be used in 5% of the new homes built	Later

In the next 20 years:	**Consensus**
Further advancement of the smart, integrated power network	75%
Use of Fuel Cells in passenger vehicles.	50%
A break-thru in fuel cell technology finally helps make them economically feasible for wide-spread commercial use	67%
Photovoltaics will dominate but efficient long distance transmission of electricity will improve	25%

Obstacles and Problems--The final area of concern was to find out what the panel of experts felt were the areas that were holding back the development of alternative energy technologies. There was not nearly as much consensus on specific items identified here, but there was strong agreement on all the following items.

Obstacles and Problems:	**Consensus**
Inexpensive oil, natural gas, and coal	100%
Current significant complacency among an uninformed public at large	100%
Political action committees	100%
Regulatory Change	100%
Lack of leadership and will at the highest levels of our political system	100%
Inertia in the energy-policy and electric-power sectors	100%
Influence of the fossil-fuel sector	100%
Insufficient public awareness of the gravity of our energy and environmental situation, most of the impediments are political--the classic sources of coal, petroleum, and nuclear have tremendous political power and will continue to receive tax credits and other incentives and will try to obstruct implementation of the true costs of production and environmental	100%
Fear of trying alternative technologies	75%
NIMBY's (Not In My Back Yard)& Tree-Huggers	75%
On the development side there are technical limitations that need to be resolved. For example looking at Ultracapacitors, the cell voltage is the key on getting a higher energy density.	75%

It is interesting to note that the last item listed in the chart was the only item identified by the panel of experts that really dealt with a technical issue. Clearly, it appears that the panel of experts believes that the obstacles are more political than technical. The assumption seems to be that if the right policies were enacted to support alternative energy developments, then there

would be progress made on a more aggressive implementation of such energies. Other obstacles and problems identified had 50% or less consensus (see below)

Obstacles and Problems:	Consensus
Fragmented thinking	50%
Old, outdated mechanistic worldviews and belief systems	50%
The status quo	50%
State & Federal programs are needed to provide financial incentives	50%
Alternative Energy Systems for their homes.	50%
Affordable source of Hydrogen for Fuel Cells	50%
Market-Oriented Solutions.	50%
End-Use/Least-Cost Thinking	25%
A Watt Saved is a Watt Earned/Demand-Side Management	25%
What Exists is Possible	25%
Systems Thinking	25%
Trying to tunnel through the Cost Barrier	25%
Not profitable enough for anyone to develop alternative energies	25%
The number one obstacle is cost.	25%

Discussion and Conclusions

This study provides educational institutions with important information for designing an alternative energy program that is responsive to the needs of the consumers and decision makers in the years to come. It is clear that the panel of experts believes that there is not a clear-cut answer to our energy use problems, but the need of an eclectic approach that is concerned with understanding the technical aspects of alternative energy, the belief that it will take more than one form of alternative energy to meet our energy needs, and the need to have a good understanding of the political process for influencing policies supportive of alternative energy source development, its effective storage, and conservation/efficiency concerns.

In order to suit the specific needs of a specific college or department these issues would have to be further drawn out. It seems logical however, that two to three semester classes could satisfy the technical portion of an alternative energies program. However, appropriate classes in political science, economics, sciences, and business management would also be necessary as indicated by the problems facing the industry.

Due to the nature of curriculum, in that it is an evolving development process, it may not be possible to just magically create an Alternative Energy program within a department that is already stretched. While it would be optimal to do so one needs to be realistic. If a department is not at a point were it is logistically feasible to create an entire program based on this research the authors recommend one or more of the following options.

> **Minor Course Revisions –** Specific instructors could alter or add to their courses where this topic applies. An instructor could adapt the current material or add one or two lectures to the course that addresses these issues. The student could be required to do a research paper or at least read a paper on the issue. The goal would be to introduce the student to these topics so that when the issue comes up on the job she or he would know the concepts and possibly the route to approach the issue.

Minor Curricular Revisions – The department or college could add one class to its current course requirements or simply add an elective. This course could introduce the students to the broad range of the subjects discussed in this paper but wouldn't prepare the student to necessarily work in the field of alternative energy although it could give interested students a spring board into an emerging field. It could be targeted to all of Engineering Technology students or a specific discipline within. This approach would introduce the students to the subject matter and prepare them to deal with specific alternative energy issues.

Addition of a Major – The addition of a major in Alternative Energy Technology to the program would offer the optimal opportunity for those students interested in the area. Optimally the program could be started all at once, but more realistically it may start out being classified as one of the options above with the goal of finally having a complete program. Clearly, there reaches a point when a larger step would be needed and the department should be aware of this and plan ahead to make that step.

All of the items listed with high consensus will need to be considered in order to create a strong alternative energy program. It's no surprise higher education institutions in the state of Michigan seem to have taken the lead in developing such programs with the support of grants. It is evident that granting agencies hope that the automotive industry and its future workforce may be able to adapt to the technology developed for efficient hybrid and electric vehicles utilizing advanced batteries, fuel cells, ultracapacitor powered vehicles and the like. Websites for some of these programs are listed in the reference section as samples for curriculum development ideas.

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