AC 2011-1456: A SEVEN YEAR REVIEW AND ASSESSMENT OF LAWRENCE TECHNOLOGICAL UNIVERSITY'S ALTERNATIVE ENERGY ENGINEERING PROGRAM INITIALLY FUNDED THROUGH GRANTS FROM THE STATE OF MICHIGAN

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A seven year review and assessment of Lawrence Technological University's Alternative Energy Engineering Program initially funded through grants from the State of Michigan

Abstract

Lawrence Technological University applied for and received two funding grants from the State of Michigan in 2003 and 2004 to develop curriculum and to establish courses in the field of Alternative Energy Engineering. Lawrence Tech in 2003 was one of five schools in Michigan to receive these initial funds. This paper reviews the decision making process originally used to establish the curriculum, the engineering courses developed through these grants, the establishment of an Alternative Energy Engineering laboratory, and the subsequent evolution of the Alternative Energy Engineering program into a full energy program housed within the mechanical engineering department at Lawrence Tech. An evaluation of the existing program curriculum is also included. A summary and discussion of the benefits to Lawrence Tech from this now well established, but still evolving program are also presented. These benefits include how this program has assisted in the school's recruitment of new engineering students, provided opportunities for collaborative work with other colleges within Lawrence Technological University as well as with local commercial industries, enhanced student senior design projects, lead to other grant funded opportunities, and how it has also directly lead to significant research opportunities for both graduate and undergraduate engineering students. Job and long-term career opportunities for recent graduates involved with the energy program are also discussed. Lastly, a discussion is included regarding what changes and additions that are planned for the energy program at Lawrence Tech to keep the program vibrant and adapting to the ongoing knowledge and understanding needs of today's engineering graduates.

1) Background

In the early spring of 2003 Lawrence Technological University (also known as Lawrence Tech) submitted a proposal to NextEnergy (a nonprofit corporation created by the State of Michigan with the mission to support and promote alternative energy within the State of Michigan) and was awarded one of five $100,000 grants in early summer 2003 to create a concentration in alternative energy in its Mechanical Engineering and Electrical Engineering programs, and to develop an Associate Degree in Alternative Energy in its engineering technology program for students interested in alternative energy. Funds for these curriculum grants originated from The Michigan Economic Development Corporation and were routed through NextEnergy for administration and management. Lawrence Tech also agreed to explore how it might incorporate its program with Focus: HOPE (an educational, job skills training and economic empowerment organization helping the inner city) in Detroit, to help educate the Focus: HOPE students about these emerging energy technologies. All official work funded by this grant began July 2003.

These initial grant funds specifically prohibited funding the purchase of any laboratory equipment or testing equipment and were to only be used for course development. This was a most unfortunate constraint, because of the need for equipment and an energy laboratory to

accompany the education of engineers. As a result, the initial curriculum development only focused on traditional classroom type lectures and educational approaches.

Lawrence Tech hired the author of this paper in the summer of 2003, initially as a College Professor in the Mechanical Engineering department to lead and oversee the complete development of the alternative energy curriculum for the university. Dr. William White, department chair of the Engineering Technology program was delegated with the responsibility of developing the Alternative Energy Engineering Technology Associates Degree (a two year program). The technology degree program, however, will not be discussed in this paper. The author was responsible for developing a series of technical electives for the Lawrence Tech Concentration in Alternative Energy in the Mechanical Engineering and Electrical Engineering programs (which are formal ABET approved four year programs).

After strong prompting from the first round of grant recipients in the spring of 2004 The Michigan Economic Development Corporation and NextEnergy initiated a second round Implementation Request for Proposals (Phase II). This Phase II RFP provided additional grant funds for up to $50,000 for alternative energy laboratory and equipment to colleges and universities in the State of Michigan to support expanded curriculum and higher learning efforts in the alternative energy field. Lawrence Tech again submitted a proposal and in the late summer of 2004 was awarded $50,000 in support of creating an alternative energy laboratory at Lawrence Tech. As a result Lawrence Tech was awarded a total of $150,000 in support of the development of their Alternative Energy program from the State of Michigan.

Over time, and since those seed funds were granted and made available, Lawrence Tech has expanded its course offerings and program beyond the alternative energy engineering concentration. The school has created an energy engineering minor, and two graduate certificates in energy.

2) Establishing Curriculum

In the late 1990's and early 2000's the price of oil, both real and nominal, and corresponding price of natural gas and coal had stopped declining and the real prices of these fuels began to increase.[1] In the early 2000's fuel cells and hydrogen were garnering a major share of the Alternative Energy stage.[2-4] The belief in the popular press at that time was that fuel cells would be the primary energy generator by the end of the decade, and because of that belief a major push had to be made to assure there was a technically educated work force to support such technology.[5] Because of this skewed enthusiasm most of the proposals for The Michigan Economic Development Corporation and NextEnergy grants focused on fuel cells and hydrogen.[6]

Lawrence Tech faculty, however, chose to develop an Alternative Energy program that dealt with all the major alternative and renewable energy systems. These renewable energy systems included wind, solar (heating and photovoltaic) biomass, geothermal, hydroelectric, as well has fuel cells and hydrogen. At that time Lawrence Tech believed that this broader view was a wiser educational approach and to embrace all of these technologies. This was because once one stripped away the hyperbole there was very strong evidence, even at that time, that no one of

these systems, especially fuel cells, would be the dominant energy technology for the near future, or for the next several years. Lawrence Tech faculty believed then and continues to believe that a mosaic of alternative energy technologies will be used to meet the growing energy demands in the coming years. This opinion is reflected in the courses developed. Lawrence Tech believed that this would better educate the student and would provide a broader understanding of the energy options available to our country.

From late summer 2003 through the end of 2003 Lansing Community College, also a NextEnergy grant recipient coordinated a serious of DACUM information panels, comprised of topic specific technical professional experts, to determine critical program curriculum content for the major alternative energy technologies. DACUM stands for "Developing a Curriculum", and is a well defined methodology used for occupational task assessment to help define educational content for a curriculum within a given career field.[7] The DACUM process has been used by several colleges and universities to develop educational curricula, and is well documented elsewhere.[8-10] Much of the Lawrence Tech alternative energy curriculum drew upon these DACUM results for the general basis of course content.

3) Learning Objectives for the Program

From the outset a primary objective for the alternative energy program at Lawrence Tech was that courses must contain much more than "survey level" content. It was felt that students should know more than just something about the technology, but rather, they should be able to design alternative energy systems and act upon the knowledge they had gained in the courses within the program. Students needed to be able to integrate knowledge, skills, and abilities to be productive engineers in the field. Lawrence Tech felt that it was not enough to "know" about the field, but to also be able to "do" in the energy field. With this in mind the outcomes associated with ABET accreditation were used as a base reference. These outcomes have since been revised with the issuance of the latest ABET criteria for accrediting engineering programs.[11] The following outcomes were further developed and deemed as adequate for each course in the program.

1. Students will be equipped to define, characterize and solve energy problems using the fundamental knowledge and tools in basic mathematical, chemical, physical, and social sciences.
2. Students will be quipped to design and conduct meaningful experiments, acquire appropriate data, analyze, and interpret those data to solve relevant energy engineering problems.
3. Students will know pertinent professional, ethical, social and environmental factors in energy engineering and understand the impact of these factors relating to global energy issues.
4. Students will complete the program with the ability to communicate technical energy related issues effectively both orally and in writing.
5. Students will gain an appreciation for lifelong learning to continue to maintain and develop added future energy related technical competency, and to stay abreast of the latest developments in the energy field.

4) Courses Developed and Offered

Courses were developed based on a combination of information obtained from the DACUM effort previously mentioned, by drawing upon knowledgeable technical and engineering

professionals within the energy field, as well as the in-house knowledge of faculty within the college of engineering. The original topical focus was to be on alternative and renewable energy systems included wind, solar (heating and photovoltaic) biomass, geothermal, hydroelectric, as well has the popular fuel cells and hydrogen. What became apparent early in the process to the faculty, outside contacts and respected advisors to the Lawrence Tech program, however, was the clear need to expand the curriculum to include traditional energy systems and to include energy management of existing energy technology systems. The original intent to keep the Lawrence Tech effort purely as an alternative energy program seemed impractical and myopic since only 7% of the overall energy used in the United States was from renewable and alternative sources.[12] Approximately 93% of the all the energy used in the United States still came from oil, coal, natural gas, or nuclear power. These overwhelmingly larger percentages and sectors of the energy field needed to still be represented in the Lawrence Tech educational picture.

So, unfortunately, the original goals for the funding from the State of Michigan to focus on just alternative energy were too narrow. Significant opportunities to make real gains in energy efficiency with traditional energy systems also needed to be included as educational components to the program. By the fall of 2004 the electric utility company for the Southeast Michigan region, DTE Energy, approached Lawrence Tech to also provide a program to give their employees education in energy and environmental management. This was clearly an important expansion of the program and, therefore, was actively pursued by Lawrence Tech.

The following courses, along with a brief description of each, were developed for the energy program at Lawrence Tech. The year each course was introduced is also listed provided in parenthesis. All courses were developed from DACUM data, with industry advisor input, and approved via the Lawrence Tech course approval guidelines.[13] Note that the prefixes for course numbers listed below, EGE, EEE, and EME, stand for Engineering General Engineering, Engineering Electrical Engineering, and Engineering Mechanical Engineering respectively, and are used in the Lawrence Tech course number nomenclature.

EGE3903 - Alternative Energy Fundamentals (2003); a overview of the alternative and renewable energy technologies available.
EEE4943 - Power Electronics (2004); electrical engineering aspects of power electronics.
EME5163/6163 - Fuel Cells and Hydrogen (2004); the science and engineering or fuel cells, and the production and storage of hydrogen.
EME 5153 - Applied Thermodynamics (2004); pertinent cycles and energy related thermodynamic topics.
EGE4921 - Alternative Energy laboratory (2005); a hands-on alternative energy lab.
EME5193 - Solar and Wind Energy Generation (2005); the fundamentals of solar heating, photovoltaics, and wind energy.
EGE 5303 - Energy and Environmental Management 1 (2005); traditional energy management in buildings and industrial facilities and the environmental impacts of those systems.
EME 5263 - Energy Resources and Technologies (2007); technical analysis of traditional energy generation systems.
EME 5283 - Elements of Nuclear Engineering (2007); fundamentals of nuclear energy and nuclear reactor power systems.
EME 5273 - Heat Pipes (2009); and advanced heat transfer technology.

EME 5293 - Fusion Engineering (2007); an engineering course focused on possible energy production from fusion reactions.
EME 5313- Biofuels and Biomass Energy Engineering (2009); energy from bio sources including ethanol and biodiesel, and more.
EGE 5323 - Energy and Environmental Management 2 (2010); an advanced course following and building upon knowledge developed in EGE 5303.

Interestingly, a helpful collaboration was initiated between the college of Arts and Sciences and the college of Engineering at Lawrence Tech and a social science course in energy was developed, SSC 3363 - Philosophy, Society and Energy, which deals with the political and social aspects of energy on a global basis. It was first offered in 2007. The SSC prefix stands for Social Science and Communication and is part of the course nomenclature at Lawrence Tech.

A complete listing and catalog descriptions of all Lawrence Tech courses can be found at the following website: https://bnras1p.ltu.edu/pls/banner_pprds/bwckctlg.p_disp_dyn_ctlg .

5) Development of an Alternative Energy Laboratory

The purpose of the Phase II grant from NextEnergy was primarily to purchase equipment for the establishment and outfitting of Alternative Energy Laboratories for colleges and universities in Michigan. The Phase II funding received by Lawrence Tech helped to create a lab that was to be used as a separate course (EGE 4921 - Alternative Energy laboratory). But because the course was not a required course for a specific degree, enrollment was low and it was found to be very difficult to expand enrollment. As a result the lab components were rolled into the content of each academic course. This actually made each course more substantive and much more relevant to the student. Topical lab testing data were collected in a timely period relative to topics covered in the regular courses. This gave students an opportunity to see how theoretical components discussed in class could be translated into real and relevant systems performance data using the equipment in the laboratory. Actual system performance losses and efficiencies could be computed. Relevant real-time data could be collected and analyzed. As a result the integration of lab and regular course materials became a more meaningful learning experience for the student. These laboratory experimental systems, some purchased and most internally developed by program faculty, included the following:

Biomass station: including biodiesel production, ethanol production, a wood and fiber drying station moisture content studies, and an oxygen bomb calorimetry energy content. Also included are a precision balance, and two drying ovens (one a vacuum drying oven) as well as two hot-plate stirring units.

Wind turbine: a small commercially available 400 watt wind turbine was purchased and installed on the roof of the alternative energy lab.

Low velocity wind tunnel: a low velocity wind tunnel with a test chamber 24” x 24” x 36” was designed and built by Lawrence Tech students. Top wind velocity for the tunnel is approximately 25 miles per hour.

Solar hot water: Three solar hot water systems are available. Two were made by LTU staff. These consist of a small flat panel hot water heater, and a small parabolic trough heater. Also an evacuated tube (10 tubes) water heater was purchased and a supporting portable test stand was built.

Solar photovoltaics: Lawrence Tech installed a 10 kW PV system on the roof of the engineering building and students are currently using the data monitoring system for educational purposes.[14] Lawrence Tech also purchased several different PV panels to give students an opportunity to test and evaluate the various PV technologies available. These PV panels were mounted on roller carts for use outside.

Hydrogen generation: Two small water electrolysis stations were purchased along with adequate power supplies for use in the lab.

Fuel cells: Two fuel cells along with related supporting hardware were purchased for the lab. These include a small 10 watt cell for use as an introductory teaching device. A second Ballard 1.2 kW NEXA fuel cell was also purchased for more significant experimentation. Several additional pieces of equipment were also purchased including two variable 1.6 kW loads, a DC/AC inverter as well as various computer tracking system components.

Hydroelectric generator: A small 400 watt hydroelectric generator was purchased and will be mounted and a small tank with a pump to circulate the water through the generator. A small load system will be used to evaluate power output at various flow and pressure levels.

Various supporting equipment was also purchased to assure adequate laboratory measurements at the various lab stations. These include volt meters, multimeters, clip leads, etc.

6) Development of the Energy Program

As the Lawrence Tech program course offering expanded and enrollment grew, the school was asked by current and potential student about possibly offering a bachelors degree in alternative energy engineering or a degree in energy engineering. Administrators at Lawrence Tech also inquired about the possibility. Faculty members in the program have remained cautious, however, about starting a new degree in Alternative Energy Engineering, or even a degree in the more generalized field of Energy Engineering. Bass and White note that “As a metric for how underserved energy engineering is in the United States, consider ABET does not list "energy engineering," or any permutation thereof, as a separate discipline.”[15] Lawrence Tech has seen an interest from its students regarding such a degree. Industry, however, does not have any familiarity with what constitutes such a degree. Would such a degree focus on the engineering of energy generation, or on the user and application side of the energy? What constitutes an educated student in the field of energy engineering? These important details are not yet fully defined within academia, the professional engineering community, or by those working in the energy field. Also, Lawrence Tech faculty in private conversations with admissions officers at other universities have learned that students who potentially might hold a BS in Energy Engineering and who might be applying to graduate schools that only offer traditional ABET recognized degree programs, could have a difficult time getting accepted to those other schools.

There are other challenges with establishing an energy engineering degree to meet ABET requirements.[16] As a result, Lawrence Tech has not yet decided to offer a formal degree in energy engineering.

To address this, however, Lawrence Tech has moved to create four energy engineering educational options. These include a concentration in Alternative Energy Engineering (9 technical elective credits), and a minor in Energy Engineering (18 credits, 6 credits core and 6 credits technical elective), at the BS level.[17] Lawrence Tech also offers two graduate certificates, a Graduate Certificate in Energy Engineering (18 credits, 6 credits core and 6 credits technical elective), and a Graduate Certificate in Energy and Environmental Management (6 credits and 12 months of industry related experience).[18, 19]

Lawrence Tech has also offered over two summers an Alternative Energy summer camp for high school students. The summer camp utilized the equipment in the alternative energy lab and gave high school students a hands-on experience with the technology. This work has been previously documented and was found to be a useful recruitment tool to assist in expanding enrollment in the college of engineering at Lawrence Tech.[20]

7) Evaluation the Energy Program

Various methods have been used to assess the energy program at Lawrence Tech. Three are discussed here. They include the number of students enrolled in classes, the research opportunities that have been provided, and the employment opportunities students from the program have been able to secure. This section of this paper also concludes with a written evaluation and interpretation of these assessment methods.

7.1) Students Enrolled

A complete table showing total student enrollment in all energy courses since 2003 is provided in the appendix of this paper. Courses in the program are typically offered once per academic year. A total of 854 students have enrolled in energy courses are Lawrence Tech. The most populated course in the program is EME 5153 - Applied Thermodynamics, which also serves as a technical elective in the Master of Science in Mechanical Engineering program. The next most popular course with 139 students enrolled is EME 5163/6163 - Fuel Cells and Hydrogen, which is a cross-listed course also available as a tech elective for MSME graduate students. EGE 3903 - Alternative Energy Fundamentals, the longest running course in the program is 3rd with 116 students enrolled.

The course with lower enrolment, though very popular with the few students who take them, such as EME 5313- Biofuels and Biomass Energy Engineering, will soon be offered only on an alternating year option.

The economic downturn in Southeast Michigan over the past two years has seriously and adversely impacted enrolment in this program. In spite of this, all the available indicators from potential students and currently enrolled students from end-of-semester course evaluations and informal conversations with students strongly suggest that there remains a high interest in the

Lawrence Tech program. The economy at this point, however, is still impacting their educational decisions. Future enrolment headcounts are anticipated to improve as the economy improves.

7.2) Research Activities

The development of the Alternative Energy laboratory has provided Lawrence Tech students and faculty numerous internally and externally funded research opportunities. Total research dollars brought in as of 2010 now exceed $819,000. Note that these funds do not include the original seed funds of $150,000. Research work relating to battery modeling, fuel cell durability and reliability, robotics and photovoltaics have all been researched and evaluated in the alternative energy lab.[14, 21] Understanding the energy usage of robots and alternative energy applications within robots has become a fertile ground for research at Lawrence Tech.[22, 23] Approximately 65 students have been involved in funded research projects. Approximately 22 students have done their senior design capstone engineering project in the lab. These have also resulted in the custom design and building of equipment for the lab. These senior design projects have significantly expanded the research capabilities of the laboratory.

7.3) Employment Opportunities

Several employment opportunities have arisen for students who are either still in or have completed this energy program. Lawrence Tech is in the heart of the automotive industry and the emphasis on alternative fuels and alternative energy systems has grown rapidly over the past several years. There is also a growing alternative energy industry in the State of Michigan in the form of manufacturers, distributors and installers of wind generation systems, solar power, biofuel producers, and geothermal systems. Over the past five years fourteen students have obtained co-op work opportunities in the energy field. Two students have obtained summer internships at the National Renewable Energy Laboratories in Golden, Colorado. Five have found full-time work directly in the energy field, and seven have found work supporting projects relating to alternative energy. One has started his own successful and quite profitable energy management company. Lawrence Tech is very proud and confident of the skills and knowledge students graduating from the program have demonstrated to their employers. This is considered a true stamp of approval and endorsement of the program, even during one of the worst job markets in the past 75 years.

7.4) Evaluation and Interpretation of Assessment of the Program

Student enrollment within a program is an obvious indicator of the interest level of students for learning the material and gaining knowledge within the field addressed by that program. Based on the student feedback mentioned above we know there are many students, both traditional and returning non-traditional students, who are quite interested in the energy field.

What we have learned at Lawrence Tech is that the interest level of students in the program, however, does not necessarily mean adequately prepared students applying to the program. Even Lawrence Tech's own current engineering students who are registering for energy courses also have some deficiencies. These deficiencies often have to do with the broad mix of disciplines

and subjects covered within the energy courses themselves. For example, the EME 5313-Biofuels and Biomass Energy Engineering course requires a baseline knowledge of organic chemistry and biology. Rarely would an electrical engineering student or a mechanical engineering student ever have taken an organic chemistry or biology courses at the collegiate level. As a result, a portion of the semester classroom time must be expended on introducing such materials to the student, even before the core topics of the course can be presented. The same can be said regarding electrochemistry for the EME5163/6163 - Fuel Cells and Hydrogen course. Other courses within the program have similar issues. To address this Lawrence Tech has started to explore the usage of on-line video lectures that can cover some of these topics outside of class, and can be accessed by students within the university's Blackboard© academic website.

Regarding returning students, some of these students have been out of college for 20 years or more. Very often these returning students are highly motivated, but their advanced mathematics skills have been lost, as has their basics in engineering, physics, chemistry, and electronics. These students often struggle in class, and much time is typically spent in office hours with them. To address this, refresher engineering courses such as thermodynamics, fluid mechanics, heat transfer, or other courses can be assigned as prerequisites to help rebuild the knowledge base for these students to succeed. A review of grade point averages of students who have been required to take these refresher courses has proven to be the most effective way to bring these non-traditional students back to performing as successful students in the program.

Another aspect of the energy program was the interest and applications from non-technical background students. These students usually had a liberal arts or business degree, and expressed great desire to enroll in the engineering courses. They were not admitted because of their very limited on non-existent technical academic background.

Another aspect of the program was that to offer quality courses required find qualified course instructors. Lawrence Tech is blessed with a large pool of very qualified adjunct faculty to draw upon for traditional courses in engineering. Energy courses, however, require field focused skills and knowledge. We occasionally found that instructors from industry with good classroom skills were not often able to delve into technical areas with a high level of proficiency. Or we found that very skilled technical instructional candidates had poor classroom skills. This has been address by having fulltime faculty work with the technically competent adjuncts to help transfer the knowledge to the faculty, or to have the full-time faculty head the course, and occasionally bring in the highly technically competent industry people to guest lecture certain class sessions. This initially took more time to coordinate these activities, but has since proved to be very successful.

Another challenge with the program has been to keep the courses fresh with updates on the latest advancements in the field. A great deal of research is going on in the alternative energy field, as well as in the traditional energy field. To help address this each energy course requires a special topics research paper the addresses specific new developments in course related topics. Depending on the course, students are free to select a topic, or they can be required to pick from a list of specific topics to write about. Students are told their paper will be reviewed and materials they find and develop may be used in future sections of the course they are enrolled in and writing the special topics paper for. Each student is required to give an oral presentation

about their selected topic to the other students in the class. This also helps fulfill one of Lawrence Tech's overall university goals of developing students with better public speaking and presenting skills.

The evaluation of employment opportunities for our energy engineering enrolled students in the Detroit metropolitan area has been challenging over the past few years. The global falling economy since 2008 has decimated employment opportunities in the Detroit area, and in the broader State of Michigan. Lawrence Tech energy engineering students, however, have been able to find employment opportunities, as documented above. The program continues to have positive feedback from regional employers, and the Lawrence Tech Office of Career Services regularly has companies seeing students who have taken courses or have received certificates.

8) Future Direction

As stated previously, the challenge of the energy engineering program at Lawrence Tech is to keep it relevant and moving forward into new areas. During the program's inception in 2003, fuel cells were all the rage. But recently Lawrence Tech has observed there has been a shifting towards advanced energy storage systems. Batteries are now important and engineers with those skills are very much in demand in Southeast Michigan.

Another emerging area, not highly spoken of in the past, is geothermal energy, particularly geothermal heat pumps. Real educational demand exists there, especially amongst architects and their supporting mechanical systems engineering staff. The Great Lakes also offer significant off-shore wind harvesting opportunities. Both were hardly discussed when the initial NextEnergy grants were issued.

Lawrence Tech intends to address these concerns with three new courses that are planned for development and offering within the next year. The XXX3 designation represents a course in development which has not yet been assigned a course number, with the "3" at the end representing 3 credits.

EME XXX3 – Geothermal Energy Engineering
EME XXX3 – Advanced Energy Storage Engineering I; electrochemistry, batteries and ultracapacitors
EME XXX3 – Advanced Energy Storage Engineering II; electrochemistry systems and safety
EME5193 - Solar and Wind Energy Generation will be broken into two courses; one focusing on solar energy and one focusing on wind and water energy.

The question still remains as to if Lawrence Tech should and will offer a degree in energy engineering. This question has not yet been answered.

Another question Lawrence Tech is asked regularly is if the school will offer courses or even an on-line energy engineering degree. Lawrence Tech currently does have an active and growing on-line and e-learning program.[24] The Lawrence Tech administration are very interested in seeing the e-learning program grow and develop. Lawrence Tech faculty in the energy engineering program have concerns and face challenges with providing an on-line program or

curriculum. The program has developed the integration of lab and in-class learning experiences. The energy program faculty have not yet determined how to do this effectively with on-line courses. Attempts at videotaping experiments and having them available for on-line review have proven ineffective. The student completely forgoes the spontaneous learning events that occur with programmed lab activities. The other concern with on-line classes is how the faculty can assure academic quality and integrity. These are not trivial issues, but the energy faculty at Lawrence Tech have agreed to continue to explore and evaluate how to effectively offer such on-line courses.

9) Conclusions and Acknowledgements

In 2003 Lawrence Tech initiated an alternative energy program which has since grown into four energy engineering educational opportunities for engineering students, with two as undergraduate options: a concentration in Alternative Energy, or a minor in Energy Engineering. The other two options are a Graduate Certificate in Energy Engineering, and a Graduate Certificate in Energy and Environmental Management. All courses in these programs also serve as tech electives for engineering students in mechanical engineering or electrical engineering, as well as serving as core courses or technical electives for the energy programs. To date 854 students have taken courses in the program. Several students have found employment as co-op students or as full time employees directly in the energy field, or in closely related fields to energy.

As always, the success of any program or academic effort depends on many people. The following individuals contributed heavily to the success of the Lawrence Tech energy engineering program. They cannot be thanked enough for their vision, help and support.

Mr. Jamal Aboueljoud – energy consultant and adjunct professor at Lawrence Tech
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Dr. Steve Howell – former department chair of Mechanical Engineering at Lawrence Tech
Dr. Badih Jawad – faculty member, Mechanical Engineering and department chair of Mechanical engineering at Lawrence Tech
The late Dr. Larid Johnston – former Dean of the College of Engineering at Lawrence Tech
Dr. Richard Johnston – faculty member, Electrical Engineering at Lawrence Tech
Mr. Robert Pratt – solar energy consultant in the Southeast Michigan metropolitan area
Dr. Kingman Yee – faculty member, Mechanical Engineering at Lawrence Tech

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APPENDIX

Table Showing Student Enrollment for all Energy Engineering Courses since the start of the program at Lawrence Tech, in 2003.

Course Number and Name	2003	2004	2005	2006	2007	2008	2009	2010	Sum
EGE 3903 - Alternative Energy Fundamentals	10	9	8	14	23	16	17	19	116
EME 5153 - Applied Thermodynamics		30	37	21	30	21	30	49	218
EME 5263 - Energy Resources and Technologies					18		23	15	56
SSC 3363 - Philosophy, Society and Energy						17		9	26
EME 4363 - Thermal Fluid System Design									
EME 5193 - Solar and Wind Energy Generation Systems			9		15	17	17	19	77
EME 5163/6163 - Fuel Cells and Hydrogen		16	20	12	31	12	31	17	139
EME 5283 - Elements of Nuclear Engineering					42		35		77
EGE 5303 - Energy and Environmental Management 1			11	6	4	7	32	14	74
EGE 5323 - Energy and Environmental Management 2								6	6
EME 5273 - Heat Pipes							7		7
EME 5293 - Fusion Engineering					28		11		39
EME 5313- Biofuels and Biomass Energy Engineering							9	10	19
Sum	10	55	85	53	191	90	212	158	854