WRIGHT STATE UNIVERSITY
&
UNIVERSITY OF DAYTON

Full Proposal
for
Master's Degrees
in
Renewable and Clean Energy

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1. Degree Program Designation: Master of Science in Engineering in Renewable and Clean Energy

This proposal is a request for degree authority for a Master's Degree in Renewable and Clean Energy for both Wright State University (WSU) and the University of Dayton (UD). The degree name will be Master of Science at UD and Master of Science in Engineering at WSU following the custom at each university. The Air Force Institute of Technology (AFIT) is also a partner in this collaboration, but is not seeking new degree authority. Our three institutions have been long-time partners in the unique and highly successful Dayton Area Graduate Studies Institute (DAGSI). Accordingly, these new degree programs will follow all DAGSI policies and procedures in terms of course and other resource sharing. Considering the similarity of the new degree programs being proposed, the Chancellor's Office (Dr. Andrist) has advised us to submit a single proposal.

The purpose of the Master of Science (in Engineering) in Renewable and Clean Energy is to provide our state and country a supply of future engineers and researchers in the critical field of energy. At the present time, our country, and the world, is facing a shortage of liquid petroleum based fuels and the potential for shortages in natural gas within the next 20-30 years. While there are significant amounts of coal available in this country, there are environmental issues related to burning coal that will restrict its use. What is needed is alternative means for producing the energy required to keep our industry strong and to maintain a high standard of living. An economical alternative to the traditional fossil fuels, that we are so dependent upon, must be developed in the near future. Hopefully, such an alternative energy source will also be renewable and clean. To make this development happen, a large work force of engineers and scientists is required. WSU, UD, and AFIT want to be at the forefront of supplying this critically needed educated work force in the area of renewable and clean energy. The goal of the programs being proposed is to satisfy a part of this need. These are the first programs of their kind in the State of Ohio.

The Renewable and Clean Energy degree programs being proposed will seek to educate students in many types of alternative energy technologies that hold promise of becoming a substantial source of energy for the United States. These technologies include solar energy, wind power, hydrogen fuels, fuel cells and nuclear energy. In addition, these degree programs will deal with the efficient use of the energy sources we already have. The program is flexible enough that other types of energy technologies can be added as the expertise becomes available. By the same token, energy forms found not to be feasible can be eliminated from the program.

WSU, UD, and AFIT each have significant faculty strength in alternative energy and energy efficiency. Thus, with the collaboration through DAGSI, there is already available a combined expertise base to bring immediate strength to the new programs. The proposed degree programs will have both thesis and non-thesis tracks. Generally, part-time students who are employed as engineers will pursue a non-thesis track. Full-time students, particularly those supported by their institutions, typically will complete a thesis. These students will undertake a research project in the area of renewable and clean energy under the supervision of a program faculty member.

These new programs will stimulate collaborative research in renewable and clean energy sources in the Dayton region.

2. Proposed Curriculum

The new degree programs, one at WSU and one at UD, both in Renewable and Clean Energy will require a minimum of 45 quarter credits at WSU and 30 semester credits at UD. The programs will offer both thesis and non-thesis tracks, as do most engineering master's degree programs at the two institutions. WSU allows 12 quarter credit hours for thesis to count toward the degree and UD allows 6 semester hours. The non-thesis options will require the students to take an equivalent number of advanced graduate course credits, including a project oriented course, to replace the thesis credits.

The program curriculum (detailed in Appendix A) will feature required courses and electives. The required portion of the curriculum includes two core fundamentals courses in Advanced Thermodynamics and Energy Materials and three courses in renewable energy systems and clean energy. These latter three courses will be selected from among four categories; namely Renewable Energy, Clean Energy Systems, Energy Efficiency, and Large Scale Energy Systems. Two to three electives beyond the strictly energy focused courses will be permitted. Finally, students will be required to take one graduate level mathematics course at WSU, UD, or AFIT and complete a thesis or take additional courses for a non-thesis option in order to satisfy the requisite credit hours of the respective universities.

The two core courses in Advanced Thermodynamics and Energy Materials are fundamental to all renewable or clean energy systems. Thermodynamics can be defined as the study of energy and a good background in thermodynamics is essential to any energy program. The program being proposed here allows an advanced thermodynamics course from the mechanical engineering viewpoint (MEE511 or ME744), a thermodynamics course from the materials and chemical engineering viewpoint (ME, CME507 or ME760), or a thermodynamics course from the physics viewpoint (PHYS635). This allows the students from a variety of disciplines to come in to the Renewable and Clean Energy program and allows students to choose the perspective from which they want to learn thermodynamics. This variety of perspectives on the core thermodynamics course is possible because of the collaboration being utilized in this program. The energy materials course is also believed to be fundamental to the Renewable and Clean energy program because of the need for all energy systems to use materials. This class will give the students a firm understanding of a number of the material aspects of renewable and clean energy systems.

The three Renewable and Clean Energy course requirements provide the student options to select from a number of courses in the renewable and clean energy arena. At the University of Dayton, one of these requirements must be in the Energy Efficiency area. Renewable Energy courses include courses in Renewable Energy Systems, Solar Energy, Hydrogen Power, Wind Energy, and Hydropower. Clean Energy courses include courses in Fuel Cells, Electrochemical Energy Storage, Advanced Fuels, Clean Coal Technology, and Nuclear Energy. Energy Efficiency courses include offerings in Energy Efficient Buildings, Energy Efficient Manufacturing, Design for the Environment, and Design of Thermal Systems. Large Scale Energy Systems course

options include Grid Power Systems, Energy Production and Transmission Management, and an Energy Research course. This range of course selections allows the student to choose the courses that are most suitable to them. If the student has a strong chemistry background, they may gravitate to the courses like Hydrogen Power and Electrochemical Energy Storage. If the student has a strong background in Mechanical Engineering, they may gravitate to courses in Solar Energy, Wind Energy, and Thermal Efficiency. If the student has a strong background in Materials Science and Engineering they may gravitate to courses in Fuel Cells and Electrochemical Energy Storage. Of course, any student can take additional courses to obtain required prerequisites to courses, making it possible for any student to take any course offered. Many of these prerequisite courses can be counted as open elective courses towards the degree as described next.

Open electives are established to broaden the student's knowledge and to give students an opportunity to take classes which enhance their research or to give the students a chance to take required prerequisite courses. These electives can be taken at WSU, UD, or AFIT. At WSU and AFIT the electives must be at the 600 level or higher, and at UD they must be at the 500 level or higher. These electives can be taken in the energy areas already listed, any engineering program, computer science, physics, chemistry, biology, or mathematics. All chosen electives must have the approval of the faculty advisor. The course numbering scheme used by the various institutions are as follows. At WSU 700 level classes are strictly graduate level courses and 600 and 500 level courses are co-listed as graduate and under graduate courses. At UD all 500 and above classes are solely listed as graduate level courses. At AFIT all courses are solely listed as graduate courses because AFIT does not have an undergraduate program. The AFIT courses listed at the 500 levels can be considered as undergraduate/graduate type courses.

Lastly students can do a thesis in an energy related area. The thesis has to be done at the student's home institution. The thesis can be up to 12 quarter credit hours at WSU and is 6 semester credit hours at UD. The non-thesis option students will complete a project that is minimally equivalent to 4 credit hours at WSU or 3 semester hours at UD. A one course equivalent project is typical of a number of traditional engineering programs for the non-thesis option; and we believe it is sufficient for the Renewable and Clean Energy program. If a student elects to take fewer than 12 quarter hours of thesis (at WSU) or pursue a non-thesis option (at WSU or UD), their remaining credit hour requirements (45 quarter credit hours at WSU and 30 semester credit hours at UD) must be attained by taking additional classes at the 700 level or above at WSU, the 600 level or above at AFIT, or the 500 level or above at UD.

Uniquely, this program will force cross-fertilization between programs in the required courses. Students must take at least one course at each of the partner universities in satisfying the five course requirement in the Core and Renewable and Clean Energy areas. It is anticipated that students will look seriously at elective course offerings beyond their host institution. The breadth of offerings afforded by the synergism made available through university collaboration is considered to be a strong asset of the program.

At the present time, most of the courses listed in Appendix A are available. All of the courses required to start this program are currently available. No new courses have to be developed. There are a total of 8 new courses that we plan to develop as part of the program. It is our

intention to develop these courses very soon after the program starts. Two of the courses listed as to be developed have faculty members from Central State University (CSU) who will come to WSU to teach them. Curriculum vitas for these two faculty members can be found on the web site: http://www.engineering.wright.edu/mme/energy/. It is WSU and UD's intent to use this collaborative teaching arrangement with Central State University to increase collaboration between CSU, WSU and UD. To further help in the development of some of the remaining six courses listed as "to be developed" WSU intends to hire one more faculty member in the area of alternative energy.

A high priority is being put on developing electrical engineering courses for the program. It is fully realized that many renewable energy technologies output electrical energy. For this reason strong electrical engineering courses are required. At the present time we have listed three courses that include electrical engineering: Electrical Power Processing, Grid Power Systems, and Energy Production and Transmission Management. The Electrical Engineering department at WSU has indicated that they would be willing to teach a power processing course for this program, as well as other courses. At the present time they have not committed an instructor to the power processing class. Because of the lack of a committed instructor at this time, these courses are listed as to be developed.

It is expected that this program will grow and respond to the energy needs of Ohio and the country. The state of Ohio will be used as the focus of case studies considered in many of the courses. The program is designed to adapt to recent findings in energy research. That is courses can be added or deleted as the research and development in renewable and clean energy dictates. In addition, it is expected that the program will be responsive to the needs of energy companies in Ohio. This will be accommodated through a strong interaction with an industrial advisory committee which will be formed to help provide direction for the program.

A unique aspect of the program will be the opportunity for graduate students in these programs to work in internships with renewable energy company partners in Ohio. DAGSI fellowships can be allocated to provide incentives for Ohio industries to hire students in this program.

Overall this program is intended to encompass a large number of Renewable and Clean Energy topics. Masters programs such as Mechanical Engineering, Electrical Engineering, Chemical Engineering, etc. cover broad topics. That is the intent with this program. It is believed that this program will find different areas of focus within the renewable and clean energy framework as the program matures. A focus area that is already emerging at WSU and UD is fuel cells. The proposed program structure allows different focus areas to develop. Even though focus areas will develop, as they do in any Masters program, we still desire to provide students with a broad range of alternative energy topics. This program should not be offered as a track in the Mechanical Engineering program because the area of Renewable and Clean Energy needs to be emphasized and isolated at this time, in this nation's history. Renewable and Clean Energy is not, and cannot be, a sideline issue in our institutions of higher education any longer. A step in getting Ohio's institutions of higher education focused on the issues of renewable and clean energy is granting this proposed Renewable and Clean Energy program Master's degree status.

3. Administrative Organization for the Proposed Program

WSU, UD, and AFIT are the three partner institutions in DAGSI. An important DAGSI principle is that each partner institution retains control of its own degree programs. Hence, through this proposal process, WSU and UD are each seeking degree authority, not shared authority for a single joint degree. A corollary to this is that each student selects one of the partner universities as a home institution. Finally, the partner institutions each agree to accept up to one-half the student's credit hours from the partner institutions (except thesis credits which are taken at the home institution). Procedures are in place to assure that this is seamless for the student, e.g. cross-registered courses are not considered to be transfer credit. The proposed programs will require cross-registration for one or more required courses and encourage cross-registration for additional courses.

Responsibility for program administration at WSU will be in the Department of Mechanical and Materials Engineering and the School of Graduate Studies. This master's degree program will adhere to the policies of the Wright State Graduate Council and the School of Graduate Studies. The contact for the program development at WSU will be Dr. James Menart, Associate Professor in the Department of Mechanical and Materials Engineering.

Responsibility for program administration at UD will be in the Department of Mechanical and Aerospace Engineering and the Graduate School, but will have linkages to Chemical and Materials Engineering, Electrical Engineering, and Electro-Optics. This master's degree program adheres to the policies of the University of Dayton's Graduate Leadership Council and the Graduate School. The contact for the program at UD will be Professor Kevin Hallinan, Chair of the Department of Mechanical and Aerospace Engineering.

At AFIT the contact for this program will be Dr. James Petrosky, Assistant Professor of Nuclear Engineering.

There will be admission committees at WSU and UD to screen applicants for the programs composed of faculty members in the departments administering these programs. There will also be a combined program committee that will advise on curricula and the expectations for cross-registration which will include, at least, the program faculty contacts at each institution.

4. Evidence of Need for the Proposed Program

There are a number of factors that dictate a need for these master's degree programs. The primary motivator is society's need for stable, clean, and economical energy sources. The recent increase in the price of oil indicates the need for other energy supplies. As of the end of 2004 the United States was only able to produce about 35% of its oil needs. It is reasonable to project that this difference between supply and demand will worsen in the future if something is not done to mitigate our dependence on oil. One way to reduce this country's dependence on fossil fuels is to develop alternative energy sources. Two key elements to developing economical energy alternatives are to educate people in this area and to increase the amount of research done in this area. The program being proposed addresses both of these issues.

A second need for a Master's program in Renewable and Clean Energy is the interest in this area by the State of Ohio. Ohio, through its Third Frontier Project and the University Clean Energy Alliance of Ohio (UCEAO), wants to encourage research in advanced energy systems. Good research stems from good educational programs. This proposed program aims to supply educated people to the State of Ohio in the fields of renewable and clean energies and to perform research in this area. Governor Strickland in his "Building Ohio Jobs" plan said that investment in renewable energy and the biomedical industry will produce 80,000 new jobs in Ohio[1]. State Senator Sherrod Brown repeated this jobs claim and went on to say Ohio is poised to become a jobs rich "silicon valley of alternative energy"[2].

A third need for a program such as this is the number of companies that are developing in the renewable and clean energy field. Recently in Ohio companies such as First Solar, UltraCell, GrafTech International, HydroGen Corporation, Pemery Corporation, Rolls-Royce Fuel Cell Systems Incorporated, ECD Ovonics, and NexTech Materials are taking root among others. A number of Ohio companies who have a stake in renewable energy and energy efficiency are shown in Figure 1. These companies, as well as others, are and will require an educated workforce. In addition, on the energy efficiency side of the equation, there is a dearth of capable engineers who are able to help Ohio reduce energy use in our residences, buildings, and industries. This program is designed to help fill these needs.

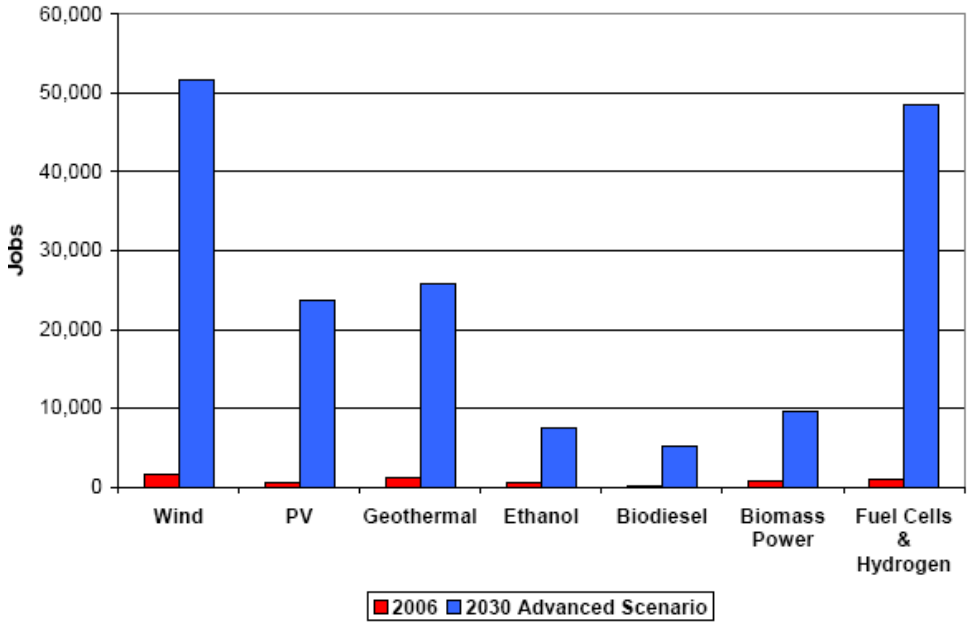
Company	Sector	Location		Company	Sector	Location
Advanced Hydro Solutions	RE	Fairlawn		North Coast Wind & Power	RE	Port Clinton
American Ag Fuels	RE	Defiance		Novar Controls Corp.	EE	Cleveland
AMTEK Solid State Controls	EE	Columbus		O'Brock Windmill Distributors	RE	North Benton
CybetUtility	RE	Cleveland		Ohio Windmill Mfg. Co.	RE	Berlin Center
Dovetail Solar & Wind	RE	Glouster		Owens Corning	EE	Toledo
Energy Technologies, Inc.	EE	Mansfield		Renewable Lubricants, Inc.	RE	Hartville
EXTOL of Ohio	EE	Norwalk		Repower Solutions	EE	Cleveland
Eye Lighting International	EE	Mentor		Schward Electrical	RE	Dayton
Energy Technologies, Inc.	EE	Mansfield		SCI Engineered Materials	RE	Columbus
Essential Research, Inc.	EE&RE	Cleveland		Solar Creations	RE	Perrysville
First Solar	RE	Perrysburg		Special Materials Research	EE	Strongsville
Forry, Inc.	EE	Chagrin Falls		SSOE Systems, Inc.	EE	Toledo
Gardiner Trane	EE	Solon		Staco Energy Products	EE	Dayton
James Leffel & Company	RE	Springfield		SunLight Energy Systems	RE	North Lawrence
Jatro Diesel	RE	Mason		Sunpower, Inc.	RE&EE	Athens
Joe Mescan Windmill	RE	Columbia Station		Technology Bus. Development	RE	North Ridgeville
Liquid Resources of Ohio	RE	Medina		Teron Lighting, Inc.	EE	Fairfield
M&B's Battery Company	RE&EE	Harrison		The Enterprise Corp.	EE	Twinsburg
Malcolm Pirnie	EE	Akron		Third Sun Solar & Wind Power	RE	Athens
Michael Byrne Mfg. Co.	EE	Mansfield		Universal Electric Power	RE	Akron
Mariner Energy Systems	EE	Brunswick		Vanner, Inc.	EE	Hilliard
Midwest Mechanical Power	RE&EE	Plain City		Venture Lighting	EE	Solon
National Electric Coil	EE	Columbus				

Source: Management Information Services, Inc. and Green Energy Ohio, 2007.

Figure 1 – Some Ohio companies with a stake in renewable energy or energy efficiency. Note that RE stands for renewable energy and EE stands for energy efficiency. This table comes from "Economic and Jobs Impacts of the Renewable Energy and Energy Efficiency Industries: US and Ohio" by Bezdek (2007)[3].

Figure 2 shows a comparative plot of the number of renewable energy jobs in Ohio in 2006 and those projected in 2030 for various industries. As this figure shows the renewable energy field can be a significant employer in the state of Ohio. Many of these jobs will require advanced skills and education; thus, highlighting the need for a Master's degree in Renewable and Clean Energy. We believe that the real question to ask is, "If we ignore the development of renewable energy and the education of our workforce in this area, what will the cost be to the state of Ohio?" This program is prefaced on the idea that renewable energy is a great growth industry; much the way the computer industry was in the 1980s and 1990s. According to the American Solar Energy Society (ASES) and Management Information Services (MISI) the renewable and energy efficiency industry in the United States has the potential to generate up to $4.5 trillion dollars in revenue in the year 2030[4].

A fourth motivation for starting a master's program in Renewable and Clean Energy is the interest in this topic seen at Wright State University and the University of Dayton. The elective energy conversion class at WSU traditionally has over 20 students enrolled, while the Renewable Energy elective course and other energy related courses at UD have enrollments of up to 35 students. Students have an interest in these topics because they know they are important to their future.



Source: Economic and Jobs Impacts of the RE and EE Industries: U.S. and Ohio[4]

Figure 2 – Number of renewable energy jobs in Ohio in the year 2006 and the projected renewable energy jobs in Ohio in the year 2030. This figure comes from "Economic and Jobs Impacts of the Renewable Energy and Energy Efficiency Industries: US and Ohio" by Bezdek (2007)[4].

A great deal more evidence for what renewable energy and energy efficiency can do for Ohio and the United States is included in the report entitled, "Renewable Energy and Energy Efficiency: Economic Drivers for the 21st Century," produced by Management Information Services, Inc. for the American Solar Society[4]. This report can be found on the world-wide-web at http://www.ases.org/ASES-JobsReport-Final.pdf .

5. Prospective Enrollment

It is estimated that enrollment for the program will reach 20 students per year at WSU and 20 students per year at UD. Enrollment in classes will be higher due to students from other disciplines attending the energy program classes. In the past large numbers of Mechanical, Aerospace, and Nuclear Engineering students have taken these courses, and it is expected that this will continue to be the case in the future. It is also believed that students from other disciplines will enroll in this program. For students from some scientific disciplines there may be a need to take some background courses as part of the program. This is no different than students who have a Bachelor's degree in one discipline and then switch to Mechanical Engineering for their Masters. It is believed that these background courses will be manageable for most scientific disciplines with some connection to the study of energy.

6. Efforts to Enroll and Retain Underrepresented Groups

Wright State University, the University of Dayton, and the Air Force Institute of Technology are all committed to enrolling students from underrepresented groups in this master's program. All three institutions have made efforts to do this in the past and will continue to do so in the future. Any recruitment done as part of this program will provide encouragement for women, minorities, and people with disabilities to enroll. DAGSI also has a recruitment program for underrepresented students that benefits all three institutions.

WSU has demonstrated a commitment to encouraging underrepresented groups to attend their university. This has been done with the many programs offered at Wright State University to make minorities and people with disabilities feel welcome. WSU was built with accessibility for disabled persons in mind. WSU's Office of Disability Services provides services to hundreds of students with disabilities. Wright State has a program called Wright STEPP which is WSU's Science, Technology, and Engineering Preparatory Program. This program focuses on students from the inner city schools of Dayton, Ohio. At the present time minorities make up 11.4% of the graduate student population in the College of Engineering and Computer Science at WSU. For the university, 15.6% of the student population is classified as a minority. The College of Engineering and Computer Science continues to work to increase the number of minority students enrolled in its programs.

UD has demonstrated similar commitment to attracting and retaining underrepresented groups. It employs a full-time engineer to manage its Women in Engineering and Minority Engineering Programs and is strengthening its relationships with Central State University, Wilberforce University, and St. Mary's University (its sister institution in San

Antonio) to help it enhance the recruitment of minorities. The University of Dayton's Minority Engineering Program (MEP) serves nearly 100 undergraduate engineering students, some of whom will naturally be drawn into this program as graduate students. In addition, UD Student Learning Support offers numerous programs and services to ensure that students with disabilities have equal access to educational opportunities at the University of Dayton so they can participate, freely and actively, in all facets of university life.

In addition to these efforts to enroll underrepresented minority students, collaboration with Central State University has been formed. This collaboration involves having two Central State faculty teach courses at Wright State University in the Renewable and Clean Energy program, recruitment of Central State students into this program, and potential research collaborations. Central State is Ohio's only historically black public institution of higher education. It is located within 25 miles of Wright State and the University of Dayton, which eliminates the distance barrier to collaboration.

7. Availability and Adequacy of Faculty, Facilities, and Support Services

The Department of Mechanical and Materials Engineering at Wright State University has 18 full time faculty members and has access to a large number of qualified adjunct instructors. All 18 of these faculty members have Ph.D. degrees and are experienced in instructing and mentoring master's level students. No new faculty members are required to run the Renewable and Clean Energy Program as proposed, but the intent is to increase the number of faculty involved in the program, especially in the area of electrical engineering. For this academic year the department specifically hired two faculty members with expertise in advanced energy systems. Next year the department plans to hire an additional faculty member who has a specialization in renewable or clean energy. Curriculum vitas for the faculty in the Mechanical and Materials Engineering program at WSU can be found on the web at: http://www.engineering.wright.edu/mme/energy/.

The class and laboratory facilities in the Department of Mechanical and Materials Engineering at Wright State University, and within the College of Engineering and Computer Science, are modern and well-equipped. These labs will provide excellent support for a new master's degree program in renewable and clean energy. The laboratory space for graduate student research is adequate to begin the program, and it is anticipated that additional laboratory space for graduate student research will be made available as research grant money increases. The College is currently making plans to start an alternative energy laboratory. The Department of Mechanical and Materials Engineering has just recently received $610,000 for the development of a Center of Excellence for Advanced Power and Energy Conversion Research. While the focus of this center will be plasma science, there is room for alternative energy research to occur within this center.

At the University of Dayton, faculty from Mechanical Engineering, Chemical and Materials Engineering, and later Electrical Engineering will be associated with this degree program. No new faculty members are required to support the proposed Renewable and Clean Energy program: however, there is an ongoing search to add another faculty to support this program. The class and laboratory facilities in the Department of Mechanical and Aerospace Engineering at the

University of Dayton are more than sufficient to support the new master's degree program in Renewable and Clean Energy. Laboratories include: Fuel Cells and Battery Laboratories; an Alternative Fuels and Combustion Laboratory; and an Energy Devices Laboratory (including supercapacitors). The University of Dayton, including the University of Dayton Research Institute, currently has energy system research grants in the $7 to $10 million range**.** Curriculum vitas for the faculty in the Mechanical, Chemical, and Materials Engineering programs at UD who will be involved in this program can be found on the web at: http://www.engineering.wright.edu/mme/energy/.

The Department of Engineering Physics at the Air Force Institute of Technology has 20 faculty members. All 20 of these faculty members have earned Ph.D. degrees. Since AFIT does not offer undergraduate programs, the entire instructional effort is directed at graduate students. No new faculty members are required to support the AFIT involvement in the proposed Renewable and Clean Energy program. The class and laboratory facilities in the Department of Engineering Physics at the Air Force Institute of Technology are sufficient to support the new master's degree program in Renewable and Clean Energy. Curriculum vitae of the faculty at AFIT who will be involved in this program can be found on the web at:
http://www.engineering.wright.edu/mme/energy/.

8. Additional Needs for Faculty and Facilities

Faculty and facilities needed for the proposed program are in place to initiate the program. Additional faculty and classroom space may be needed as the program grows over time, but current faculty and facilities are sufficient to run the Renewable and Clean Energy program as laid out in this proposal. While we have proposed to add eight new courses (two of the eight will be taught by CSU faculty), the Renewable and Clean Energy program can be implemented successfully without these courses. It is expected that these courses will be added as the program evolves and grows. Strong efforts are underway to involve Electrical Engineering faculty in the program.

9. Projected Additional Costs and Evidence of Support

The program will be financially self-supporting from the beginning at the University of Dayton and Wright-State.

University of Dayton
Administration of the program will initially be managed by the Department of Mechanical and Aerospace Engineering. All courses proposed are already offered on a consistent basis (at least every other year) within the Departments of Mechanical and Aerospace Engineering, Chemical Engineering, and Materials Engineering. Additionally, the synergism between the collaborating universities permits growth of course offerings without cost. Thus, no monies are required to hire new faculty or develop new courses. With program growth, a program director may be required.

Estimated enrollments range from 10-20 students annually. It should be noted that current enrollment in Mechanical Engineering of students interested in the energy area is on the order of 15. We expect these students and future students with interest in this area will enroll in the Masters of Renewable and Clean Energy. We further expect that this program may be particularly useful in attracting international students.

Wright-State University

The program at Wright State will be self supporting. All the courses required to begin running the program are in place and do not require additional resources. For the courses that are to be developed Wright State is currently looking to hire one new faculty member. This new faculty member has already been budgeted and will not require additional funds. It may be that Wright State will also hire some adjuncts to teach some of the "to be developed courses". This cost will be minimal and covered by the additional tuition revenues that the course brings in.

Estimated enrollment at Wright State is also 10-20 students annually. In additional to tuition income, it is believed that research grants will be brought in because of this program.

Summary

We can confidently conclude that there is little risk in implementing this program. While all the funds required to start this program are minimal, we are presently applying for $1.6 million of funding from the Department of Energy to help improve and advance this program. This funding is not needed to initiate and sustain the program.

10. Advisory Committee Involvement

The Advisory Boards for the Department of Mechanical and Materials Engineering at WSU and the Department of Mechanical and Aerospace Engineering at the University of Dayton will be used to provide advice on the Renewable and Clean Energy Program. These boards are made up of professionals within the region who work in industry and government. Most of the board members are engineers who are knowledgeable in a number of engineering topics. A board for the Renewable and Clean energy program will be started in the future.

There will be admission committees at WSU and UD to screen applicants for the programs. These committees will be composed of faculty members in the departments administering these programs.

References

1. Hershey, W., “Bond issue centerpiece of Strickland’s plan,” Dayton Daily News, February 7, 2008, p. A6.

2. Beyerlein, T. “Brown confident Oho poised to be jobs-rich, ‘silicon valley’,” Dayton Daily News, February 12, 2008, p. A5."

3. Bezdek, Roger, “Economic and Jobs Impacts of the Renewable Energy and Energy Efficiency Industries: US and Ohio,” produced by the Management Information Services, Inc. and presented at Solar 2007, Cleveland, Ohio, July, 2007.

4. Bezdek, Roger, “Renewable Energy and Energy Efficiency: Economic Drivers for the 21st Century,” produced by the Management Information Services, Inc. for the American Solar Energy Society, ASES, 2007.

APPENDIX A
Curriculum for the Masters of Science Degree in Engineering in Renewable and Clean Energy

Students from WSU and UD will be expected to take five required courses; two Core Energy courses and three Renewable and Clean Energy courses. Additionally, both WSU and UD students will be required to take a mathematics course, two to three elective offerings, and chose a thesis or non-thesis option. Non-thesis students will be expected to take at least one project course and will make up the deficit in required credit hours (45 quarter credits at WSU and 30 semester credits at UD) with additional courses.

Distinctively, this program will require students to register for at least one course at each of the partner schools. This course must be one of the Core or Renewable and Clean Energy courses. Additional cross-registration will be encouraged; however, a majority of the courses taken must be at the host school.

REQUIRED CORE ENERGY COURSES

Students are required to take 1 course to meet the Advanced Thermodynamics requirement and one course to meet the Energy Materials requirement.

- **Advanced Thermodynamics Requirement (1 among the following required)**
  - UD/MEE511 – Advanced Thermodynamics
  - UD/CME507 – Advanced Thermodynamics
  - WSU/ ME744 – Advanced Thermodynamics
  - WSU/ME760 – Thermodynamics of Solids
  - AFIT/PHYS635 – Thermal Physics
- **Energy Materials Requirement (1 among the following required)**
  - UD/MAT590 – Energy Materials
  - WSU/ME890 – Advanced Energy Materials

REQUIRED RENEWABLE AND CLEAN ENERGY COURSES

Students are required take 3 courses in the Renewable and Clean Energy area. This area comprises four categories: Renewable Energy, Clean Energy, Energy Efficiency, and Large Scale Energy Systems. The courses can be taken in a single category or in different categories. At the University of Dayton, one of these must be in the Energy Efficiency area.

- **Renewable Energy**
  - WSU/ ME623 – Energy Conversion
  - WSU/ ME624 – Solar Engineering
  - WSU/ME890 – Photovoltaics
  - WSU/ME890 – Hydrogen Energy
  - UD/MEE573 – Renewable Energy Systems
  - UD/MEE590 – Advanced Fuel Technology (including biomass)
  - Wind Power Generation and Storage (to be developed)
  - Electrical Power Processing – A modern electrical engineering course that studies the processing of electrical power from wind energy, solar energy, etc. to electrical power

that can be placed on the electrical grid or used by modern appliances (to be developed)
- CSU/– Hydropower Development (to be developed)

- **Clean Energy**
  - AFIT/NENG620 – Nuclear Reactor Theory and Engineering
  - WSU/ ME699 – Fuel Cell Science and Technology
  - UD/MEE/CME 524 – Fuel Cell Fundamentals and Technology
  - UD/MEE/AEE 526 – Advanced Fuels
  - WSU/ ME890 – Electrochemical Energy Systems
  - CSU/ – Environmental Advances in Coal Based Power Plants (to be developed)
- **Energy Efficiency (1 required at the University of Dayton)**
  - UD/MEE569 – Energy Efficient Buildings
  - UD/MEE571 – Design of Thermal Systems
  - UD/MEE 572 – Design for Environment
  - UD/MEE 578 – Energy Efficient Manufacturing
- **Large Scale Energy Systems**
  - Grid Power Systems (to be developed)
  - Energy Research course. This will be an evolving course to study energy use in the Miami Valley and Ohio (to be developed)
  - Energy Production and Transmission Management. This course will look at managing and optimizing energy portfolios statewide and nationwide (to be developed)

REQUIRED MATH COURSE

Students are required to take 1 graduate level math course.

ELECTIVES

Students will need to take 2 to 3 graduate level elective courses to fulfill the 45 quarter credit degree requirement at WSU and the 30 semester credit degree requirement at UD. These courses can be taken in the Engineering, Computer Science, Physics, Chemistry, Biology, or Math disciplines. Additional Renewable and Clean Energy courses may be taken to fulfill this elective requirement also.

THESIS OPTION

At WSU students can take up to 12 quarter hours of thesis credits and at UD students can take 6 semester hours of thesis credits.

NON-THESIS OPTION

Students who elect to do the non-thesis option must replace thesis credits with graduate level courses. At WSU these courses must be at the 700 level or above, at UD these courses must be at the 500 level or above, and at AFIT these courses must be at the 600 level or above. At least one of these courses must be a project orientated course.

*At least half the credit hours must be taken at the student's home institution.

APPENDIX B
Course Descriptions

• Advanced Thermodynamics Requirement

- UD/MEE511 – Advanced Thermodynamics (3 semester credits)
  Equilibrium, first law, second law, state principle and zeroth law; development of entropy and temperature from availability concepts; chemical potential, chemical equilibrium and phase equilibrium. Thermodynamics of irreversible processes; Onsager reciprocal relations; application of these concepts to direct energy conversion
- UD/CME507 – Advanced Thermodynamics (3 semester credits)
  Entropy balance, thermodynamics of energy conversion, mixtures, equilibria and current applications.
- WSU/ ME744 – Advanced Thermodynamics (4 quarter credits)
  Thermodynamics is studied from both the classical (macroscopic) and statistical (microscopic) viewpoints with emphasis on statistical thermodynamics. Property relationships, Maxwell relations, partition functions, distribution functions, kinetic theory and the Boltzmann transport equation are discussed.
- WSU/ME760 – Thermodynamics of Solids (4 quarter credits)
  Thermodynamics of solutions, reactions, phase transformations, surfaces and interfaces, and point defects. Quasi-chemical model for solutions. Heterogeneous phase equilibria. Phase diagrams and thermodynamic quantities.
- AFIT/PHYS635 – Thermal Physics (4 quarter credits)
  Treats statistical mechanics and thermodynamics. Topics include statistical methods, statistical thermodynamics with applications, ensemble theory, Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics with applications.

• Energy Materials Requirement

- UD/MAT590 – Energy Materials (3 semester credits)
  In this course various advanced energy technologies (AMTEC, Fuel Cells, RTG's, Thermoelectrics, Nuclear/Irradiation effects, etc.) are discussed with an emphasis on the role that materials serve in their development. Critical issues in materials development delaying the introduction of new advanced energy systems are identified along with how material selections are made based on operational system environments
- WSU/ME890 – Advanced Energy Materials (4 quarter credits)
  The course will cover advanced topics on the thermodynamics of materials and defect chemistry in solid ionic conductors. Materials related to energy applications, such as fuel cells, batteries, capacitors, and solar cells etc., as well as characterization techniques will be discussed.

.• Renewable Energy

- WSU/ ME623 – Energy Conversion (4 quarter credits)
  Study of basic energy conversion processes and the science that goes along with energy conversion, electrical power interfacing requirements, and many types of energy conversion processes both alternative and traditional.
- WSU/ ME624 – Solar Engineering (4 quarter credits)

Solar radiation, flat plate collectors, concentrating collectors, hot water heating, photovoltaic systems, and thermal energy storage will be discussed. The most time will be spent on thermal radiation systems with only a small amount of time on photovoltaics.

- WSU/ME890 – Photovoltaics (4 quarter credits)
  Photovoltaics is the basic phenomenon employed in solar cells to convert directly solar radiation into electricity. This course will discuss the physical background of solar cells, most important materials and technologies, path from the cell to the module to the system, and important applications. The role of photovoltaics in future energy systems is also considered.
- WSU/ME890 – Hydrogen Energy (4 quarter credits)
  Hydrogen provides a desirable substitute for carbon-based fuels. In contrast to carbon based fuels, hydrogen is basically abundant and its burning generates water, i.e., an absolutely harmless and recyclable "waste". This course will discuss different aspects of hydrogen utilization as a desirable fuel, including hydrogen production, storage and energy generation.
- UD/MEE573 – Renewable Energy Systems (3 semester credits)
  Introduction to the impact of energy on the economy and environment. Engineering models of solar thermal and photovoltaic systems. Introduction to wind power. Fuel cells and renewable sources of hydrogen
- Wind Power Generation and Storage (to be developed) (4 quarter credits)
  This course will discuss the basic principles of fluid mechanics that are pertinent to wind power turbines, as well as global wind patterns, the electrical power that can be extracted from the wind, the wind turbine, the wind tower, and the wind generator. Methods of controlling the speed of the wind turbine and generator will also be discussed.
- Electrical Power Processing (to be developed) (4 quarter credits).
  A modern electrical engineering course that studies the processing of electrical power from alternative energy devices such as wind energy, solar energy, fuel cells, etc. to electrical power that can be placed on the electrical grid or used by modern appliances
- CSU/ – Hydropower Development (to be developed) (4 quarter credits).
  Hydraulics of turbo machines for power generation; hydrologic analysis for hydropower development for run-of-the-river systems and reservoir systems; dams and environmental impacts; environmental impact assessment; operations of reservoir systems; economics of hydropower generation

- **Clean Energy**

- AFIT/NENG620 – Nuclear Reactor Theory and Engineering (4 quarter credits)
  This course presents nuclear reactor theory, building upon the coverage of nuclear physics (reactions, radiations, fission, etc.) and the coverage of neutron diffusion, prompt fast criticality and prompt kinetics. Delayed and thermal neutrons are incorporated into the treatment of criticality and kinetics. Reactor dynamics are examined, including aspects of reactor core and system design which provide reactivity feedback for reactor control. Nuclear reactor engineering topics include thermal management, energy conversion, radiation shielding, and mechanical and structural aspects of reactor and system design. This course provides a broadened exposure to applications of nuclear science, and provides the necessary foundation for the study of space nuclear power and of the nuclear fuel cycle.

- WSU/ ME699 – Fuel Cell Science and Engineering (4 quarter credits)
  A fuel cell converts chemical energy into electrical energy and some thermal energy by means of a chemical reaction between hydrogen-containing fuel and oxygen. As compared to other energy sources, fuel cells provide advantages that include low or zero pollution, high efficiency, high energy density and simple fuel recharge. Fuel cells can be used in electrochemical engines, portable power supplies for various microelectronic and communication devices, standby power supply facilities, power generating systems, etc. Fuel cells utilize renewable resources and provide an alternative to burning fossil fuels to generate power. Fuel cells will be the "engine" that drives the growth of future "hydrogen economy." This course will provide the students with the knowledge about fundamentals, technologies and applications of state-of-the-art fuel cells.
- UD/MEE/CME 524 – Fuel Cell Fundamentals and Technology (3 semester credits)
  The course will cover fundamental as well as engineering aspects of fuel cell technology. Specifically, the course will cover basic principles of electrochemistry, electrical conductivity (electronic and ionic) of solids and development/design of major fuel cells (alkaline, polymer electrolyte, phosphoric acid, molten carbonate and solid oxide). A major part of the course will focus on solid oxide fuel cells (SOFC), as it is emerging to be dominant among various fuel cell technologies. The SOFC can readily and safely use many common hydrocarbon fuels such as natural gas, diesel, gasoline, alcohol and coal gas.
- UD/MEE/AEE 526 – Advanced Fuels (3 semester credits)
  Basic elements of hydrocarbon fuel production including petroleum based fuels and alternative fuels. Fuel properties, specifications, handling, and logistics. Introduction to chemical kinetics and the chemistry associated with liquid phase thermal-oxidative degradation of fuels. Introduction to the computational modeling of fuel thermal stability and fuel systems.
- WSU/ ME890 – Electrochemical Energy Systems (4 quarter credits)
  The course will look at electrochemistry in fuel cells, batteries, and supercapacitors at an advanced level. Topics include electrochemical potentials, electrochemical double layer structure, electrochemical reaction kinetics, charge transport, and mass transport.
- CSU/ – Environmental Advances in Coal Based Power Plants (to be developed) (4 quarter credits).
  Coal as a source of thermal energy – historical perspective; sources of coal in the world; future dependence on coal for energy; power production using coal; general process description and flowsheeting; principles of combustion, conventional combustion reactors, environmental impact due to emissions of sulfur and nitrous oxides; fluidized bed reactors, design, process improvements in minimizing emissions; recent advances in fludized bed reactors and discussions on future innovations in technology for clean coal power production.

- **Energy Efficiency**

- UD/MEE569 – Energy Efficient Buildings (3 semester credits)
  Topics dealing with thermal environments and methods of control. Included are psychometrics, solar radiation, heat transmission through solid boundaries, industrial and residential environments, residential heating and cooling load calculations.
- UD/MEE571 – Design of Thermal Systems (3 semester credits)

Integration of thermodynamics, heat transfer, engineering economics, and simulation and optimization techniques in a design framework. Topics include design methodology, exergy analysis, heat exchanger networks, thermal-system simulation and optimization techniques.

- UD/MEE 572 – Design for Environment (3 semester credits)
  Emphasis on design for environment over the life cycle of a product or process, including consideration of mining, processing, manufacturing, use, and post-life stages. Course provides knowledge and experience in invention for the purpose of clean design, life cycle assessment strategies to estimate the environmental impact of products and processes, and cleaner manufacturing practices. Course includes a major design project.
- UD/MEE 578 – Energy Efficient Manufacturing (3 semester credits)
  This course presents a systematic approach for improving energy efficiency in the manufacturing sector. Current patterns of manufacturing energy use, the need for increased energy efficiency, and models for sustainable manufacturing are reviewed. The lean-energy paradigm is applied to identify energy efficiency opportunities in industrial electrical, lighting, space conditioning, motor drive, compressed air, process heating, process cooling, and combined heat and power systems**.**

- **Large Scale Energy Systems**
  Presently, no such courses exist, but long-term growth of this program is anticipated to lead to connections to electrical engineering, with special focus on integration of renewable and clean energy systems into the power grid. Power System Planning and Reliability, High Voltage Engineering, and Distribution System Engineering courses would be the likely focus of this expansion.

APPENDIX C
Faculty Vitae

Faculty

CURRICULUM VITAE OF ALL FACULTY FROM WSU, UD, AFIT AND CSU CAN BE FOUND ON THE WEB SITE

http://www.engineering.wright.edu/mme/energy/