P.C. Rossin College of Engineering & Applied Science

Master of Engineering
Energy Systems Engineering Program
Smart Campus Energy Systems Demonstration DE-SC0005523

1.) Program Description

A. Program Purpose and Position: The mission of the Master of Engineering in Energy Systems Engineering program is to invigorate the pipeline of new engineering graduates interested in energy oriented careers and thus produce a new generation of technical leaders for the energy and power industries. Over the next decade, nearly 50% of the skilled workers and technical leaders in the gas and electric utility industries will retire -- a much larger void than the current available and qualified professionals could fill. [CEWD, 2012 survey]

This gap creates workforce hiring challenges for all energy industries. The challenge is increased because engineers represent only 4% of bachelor's degree graduates in the United States, down from 6% in the 1960s. Overall US bachelor's degrees have more than tripled during that period [S&E Degrees, 1966-2008, NSF 11-316, June 2011].

Graduates of the Lehigh M.Eng ESE program will help close that gap and with specialized knowledge and experience such that they are readily able to tackle the challenges facing the U.S. utility and energy infrastructure, its operations, and its environmental impact. By including mathematicians, physicists and other scientists in the program, this program is developing a new pipeline for analytical talent from new and diverse sources.

B. Target Graduate Competencies: Graduate competencies at time of graduation

<u>Knowledge</u> - Program graduates are expected to have:

- clear mastery of core energy system fundamentals in project management, generation, transmission, distribution, smart grid and environmental impacts.
- recognition that deeper knowledge is available in these and other energy fields, and the ability to frame questions to experts to gain that knowledge.
- ability to contribute, for some graduates, to the advancement of knowledge in that chosen field, either via their industry projects or their chosen career.

<u>Application</u> - Program graduates are expected to have:

- ability to develop and complete complex, unstructured projects and problems in the field of energy systems engineering
- ability to contribute to successful completion of their organizations goals and objectives, exceeding expectations for new professional staff
- understanding of the ethical, safety and business implications of technical decisions.

Context – Program graduates are expected to have:

- ability to determine how their career aspirations and knowledge base can develop in specific energy sector(s)
- understanding the integration of technological, economic and environmental opportunities and constraints within the energy industry and the ultimate societal impacts, including the potential future states dependent on changes to those components

Communication - Program graduates are expected to have:

- excellent communication skills, demonstrating verbal, graphic and written abilities applied appropriately for a variety of diverse audience sizes and constituencies
- understanding of the information needs of colleagues and organizational leadership, and ability to present that information in a way the recipient can best understand and use the information
- ability to construct compelling explanations of, and potentially arguments for, the conclusions they reach through the investigative process

Leadership - Program graduates are expected to:

- work effectively with others, understanding the effects of their own communications and actions on others' thinking, motivation and behavior
- work effectively with others of complementary capabilities, forming alliances to assemble all talents necessary to leverage a superior outcome
- proactively guide or support others in ethical decision-making and action, focusing on direct and indirect contributors to safety and integrity of results
- recognize others' potential contributions according to their backgrounds and experience/education, take an active role in developing others, and assemble and lead productive teams.

C. Curriculum Descriptions: Core Curriculum (15-18 credits)
All students complete a 15 to 18 credit core sequence that provides a foundation of knowledge for success in the energy and power industries and identifies challenges facing the U.S. utility infrastructure, its operations, and the mitigation of its environmental impact.

ESE 401: Energy Generation (3 credits)
This course provides an overview of the different methods of generating electricity, such as turbine driven electrochemical generators, fuel cells, photovoltaics, and thermoelectric devices. Topics include traditional generation via fossil fuels (coal, natural gas, and oil), nuclear fission and fusion, with a focus on implementation of clean energy generation systems via renewable resources (solar, wind, hydro, tidal, and geothermal sources). Sustainability and energy efficiency issues are also addressed.

ESE 402: Transmission and Distribution / Smart Grid (3 credits)
This course provides an overview of modern power transmission and distribution systems. Topics include infrastructure, transformer technology, transmission grids, load management, distribution optimization, power supply reliability, security and deregulation. .This course has special focus on Smart Grid technologies that enable distributed renewable energy resources (generation and storage) via control, automation and intermittency management, including student research on current topics.

ESE 403: Energy and the Environment (3 credits)
This course provides an overview of the direct and indirect impact of energy generation and transmission technologies on the environment. Topics include global climate change, clean energy technologies, energy conservation, air pollution, water resources, and nuclear waste issues.

ESE 405: Energy Systems Project Management (3 credits)
This course introduces students to the basics of project management of energy systems, which includes the broad spectrum of empirical, theoretical and policy issues of managing the electric power grid, its generation facilities and equipment. This course focuses on the key elements of case studies in engineering that focus on the effective project management of tomorrow's intelligent energy system, and includes course work in engineering economics.

ESE 460: Energy Systems Engineering Project (3-6 credits)
This course provides an opportunity for students to work with energy industry sponsors and mentors on a collaborative and intensive project in an area of energy systems engineering, with an emphasis on direct industrial applications. A written report plus a poster presentation or oral presentation is required.

Technical Electives (12-15 credits)
Students acquire a level of specialized knowledge and experience through the completion of four to five technical elective courses, selected from a large pool of designated courses. Electives should reflect the student's career interest.

- Two (2) electives must be 400 level courses and
- Three (3) electives must be in the P.C. Rossin College of Engineering and Applied Science

A list of current approved electives can be found in Appendix 1.

D. Student Learning Outcomes:
Student outcomes are focused in elevating the integrated technical, business and communication abilities of graduates.

Via a combination of industry led core courses and faculty based technical electives, students *gain and apply knowledge and depth in specific technical areas* related to the energy industry and their own interests.

The students' technical understanding of energy systems and industry project research and project management will be *integrated with business (financial, economic, policy and regulatory) concepts that will strengthen their overall productivity in energy industry careers*.

Through the combination of technical knowledge in the context of real world business, economic and environmental challenges, the graduates will be able to *work more independently and produce higher quality, elevated analyses and project results* that consider the wide variety of solution requirements.

Students will have *improved business presence*, attributable to career coaching, career fair coaching and practice, personal resume advice, coaching for and participation in networking events, communications and conflict management skills assessments and tip sheets. Through this intensive communication experience, students will not only gain the positions they want, but *their career trajectory will ramp faster* than students without these skills

E. Measurable Outcomes - At the time of graduation, students will have:

- prepared research/project papers in all core courses that demonstrate their analytical, problem-solving and research capabilities, and their organizational skills
- researched intelligent electric energy systems technologies that aid in the deployment of clean energy generation systems
- prepared and given oral presentations in all core courses, and also have created and presented a technical poster at a competition and the ESEI symposium, significantly elevating their written and verbal communication skills.
- independently selected and researched technical topics of their own choosing, for the purpose of enlightening their class peers.
- visited at least three physical energy sites related to their core courses, with an experienced guide.
- worked with industry sponsors and industry mentors on their energy system project to gain insights, advice and an understanding of energy industry processes.
- strengthened their technical expertise through energy-related elective courses related to their interest areas.

2.) Academic Strength Assessment

Surveys were conducted of program Alumni, their Employers and the program Strategic Advisory Council (SAC). The surveys had reasonable response rates, except for the Employer responses, as was expected. Also, some Employer written answers imply that they were written by graduates, not employers.

- Alumni: 26 respondents out of 74 requests 35%
- Employers: 10 respondents out of 74 requests 14%
- SAC 6 respondents out of 10 requests 60%

The surveys posed 22 questions to each group, with 18 multiple choice questions for the Alumni and 15 each for the Employers and SAC. The other questions required written responses, and many written responses were provided.

Most of the multiple choice questions had 5 levels of response (e.g. very effective to not effective).

Overview:

At a high level, the positive response rate is good. The average percentage of most positive responses (e.g. neutral to very effective) was:

- Alumni 89.1%
- Employers 99.0%
- SAC 96.3%

The highest percentage of positive response, with 100% of Alumni selecting the best two categories, was in answer to the question:
"*13. How effective are the seminars/field trips at introducing students to special topics related to energy systems engineering practice?"*

The written responses provide some insight into the responses.

- Some respondents recommended adding even more technically rigorous course, applicable to their employment. The additions of Advanced Electricity Economics and Power Systems courses have specifically responded to this suggestion.
- Students like and want choice in projects, more hands on projects, projects to work in teams (real world), improved communications with their mentors. Early discussions with students regarding their interests and competencies engage them in this process.
- In general, the Alumni indicated the program curriculum was appropriate, with some individual recommendations for more on Energy Markets/Trading, Finance, Power Flow, which have been added, as well as encouragement for as many field trips as possible.

- SAC members are looking for more emphasis on presentation and writing skills, as well as business fundamentals (Ethics, Root Cause Analysis), which have been increased and added to the coursework.
- SAC also believes more industry support, more promotion, more field trips and increased promotional activity would be valuable.

3.) Sustainability Strength Assessment

A. Student Demand of Sufficient Quality

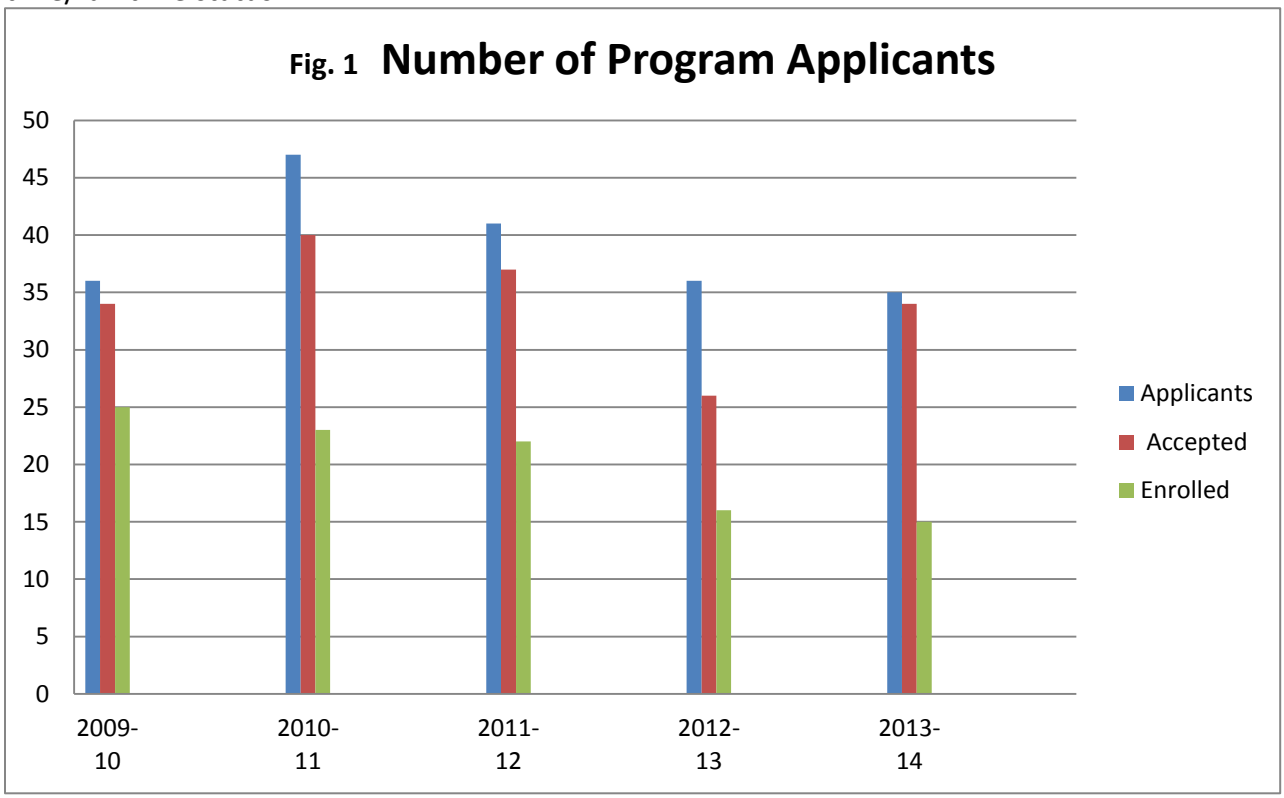
1. Student Profile

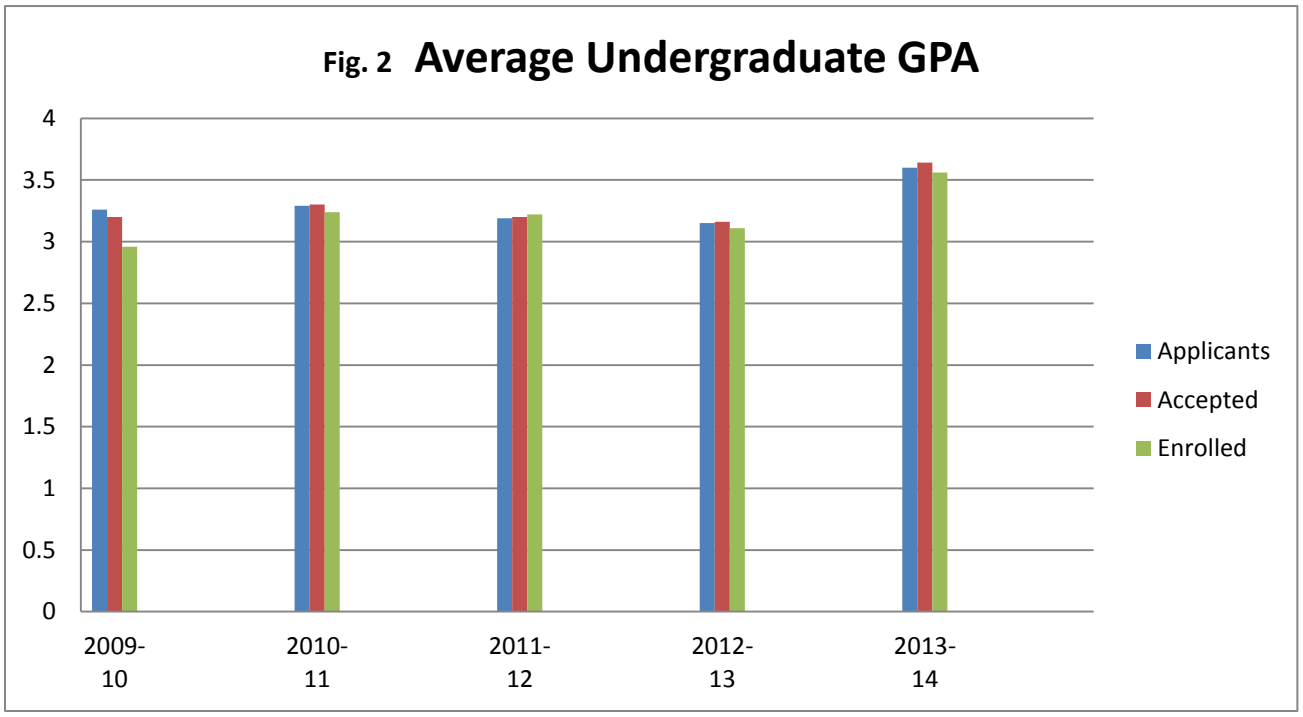
<u>Admissions Criteria</u>

- Students with a Bachelor of Science degree in any engineering discipline (including Material Science and Computer Science), physics, or mathematics may apply to this program. Admitted students may be required to take additional courses to improve specific academic deficiencies before starting this program. For example, students must have had equivalent coursework in the areas of physics, and differential equations. Other bachelor degrees are considered on a case by case basis.
- Applicants should have earned a Bachelor's of Science degree (B.S.) or equivalent (e.g., A.B.) and an undergraduate GPA of at least 2.75 out of 4.00.
- Minimum course requirements include:
    - Two years of calculus, through differential equations
    - One year of physics
- GRE's are not required for graduates of ABET accredited engineering programs in the United States. International students are required to take the GRE (Graduate Record Examination). We do not require the GRE subject test.
- The TOEFL (Test of English as a Foreign Language) is required for all applicants whose native language is not English.
    - If the applicant has received a degree in the United States, this test is waived.
    - The minimum required score is 550 on the paper test and 213 on the computer version. The essay rating should be between 4.0 and 6.0.
    - The TOEFL is only valid for two years from the date the test was taken
    - Individual skill section score recommendations for Lehigh University and the iBT (Internet based TOEFL) are:
        - 79 composite score
        - 20 Writing, 20 Speaking, 20 Reading, 15 Listening

<u>Qualifications and Characteristics of Applicants, Admitted and Enrolled Students</u>

See Figures 1-8 for statistics on number of applied and admitted students: actual enrollments; average standardized test scores and undergraduate GPA averages of applying, admitted, and enrolled students; citizenship; average age; sex; and part-time/full-time status.





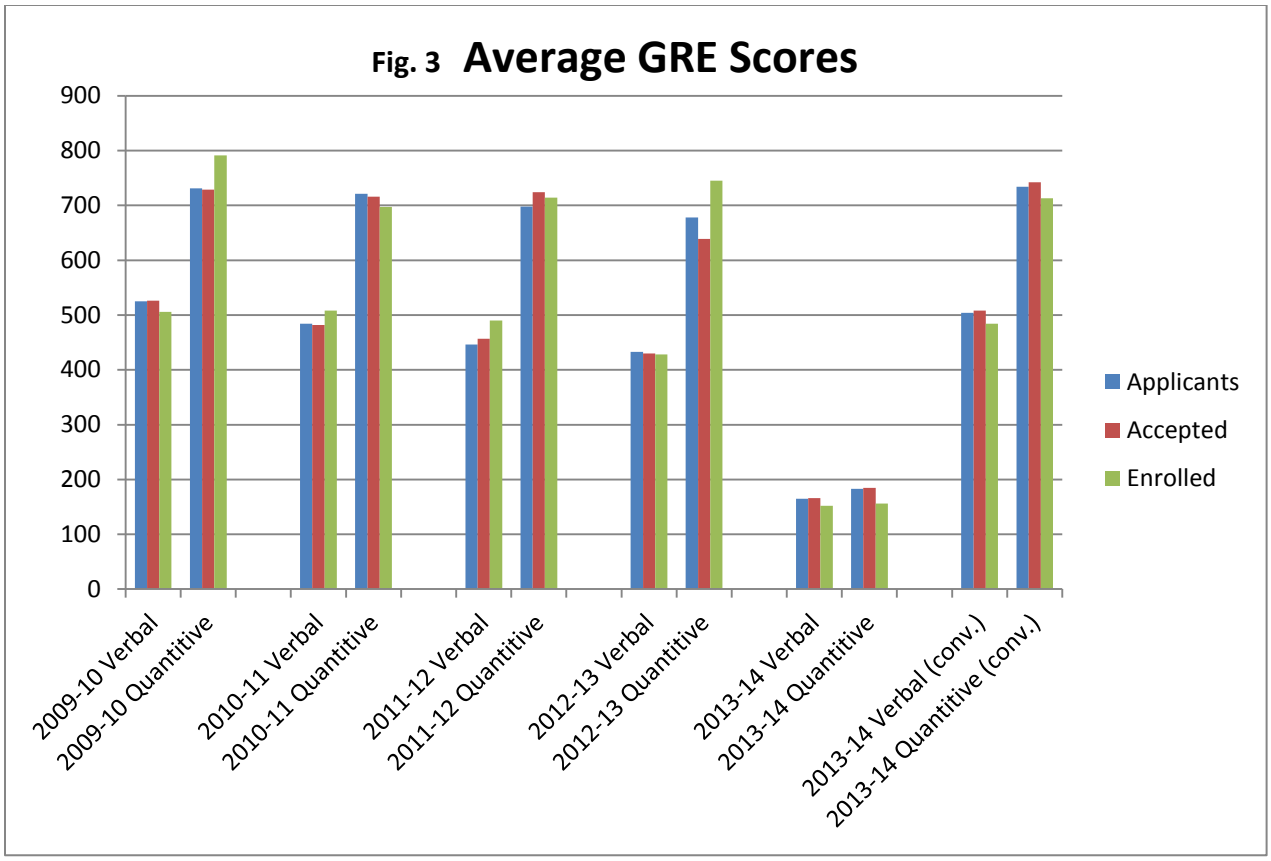


Fig. 3 Average GRE Scores
900
800
700
600
500
400
300
200
100
0
2009-10 Verbal
2009-10 Quantitive
2010-11 Verbal
2010-11 Quantitive
2011-12 Verbal
2011-12 Quantitive
2012-13 Verbal
2012-13 Quantitive
2013-14 Verbal
2013-14 Quantitive
2013-14 Verbal (conv.)
2013-14 Quantitive (conv.)
Applicants
Accepted
Enrolled

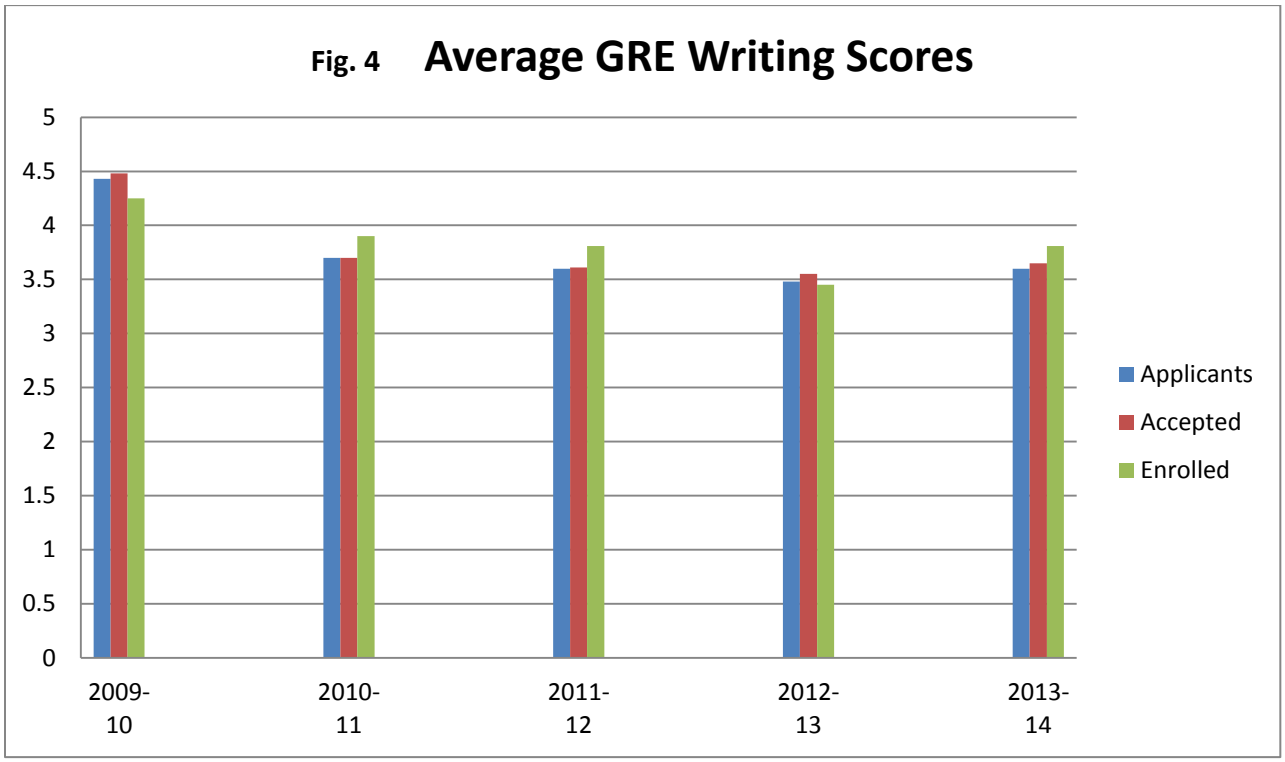


Fig. 4 Average GRE Writing Scores
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2009-10
2010-11
2011-12
2012-13
2013-14
Applicants
Accepted
Enrolled

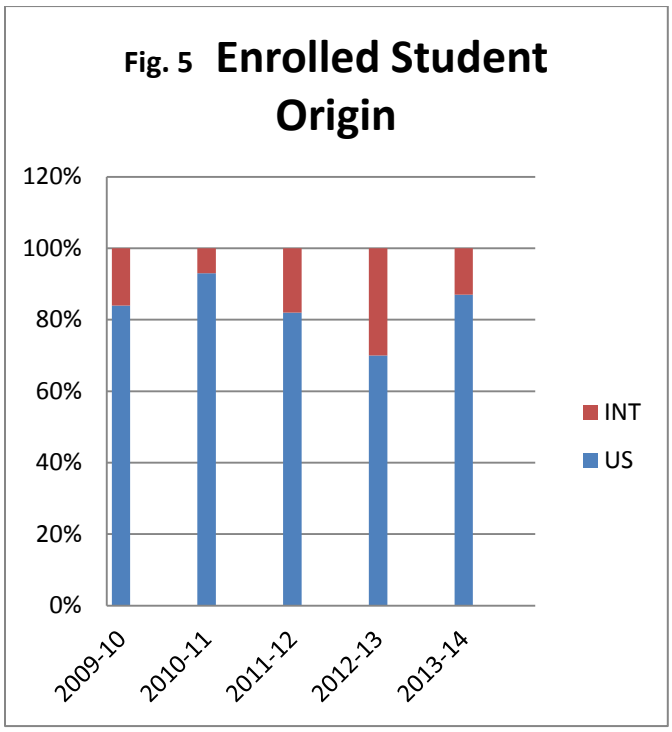


Fig. 5 Enrolled Student Origin
120%
100%
80%
60%
40%
20%
0%
2009-10
2010-11
2011-12
2012-13
2013-14
INT
US

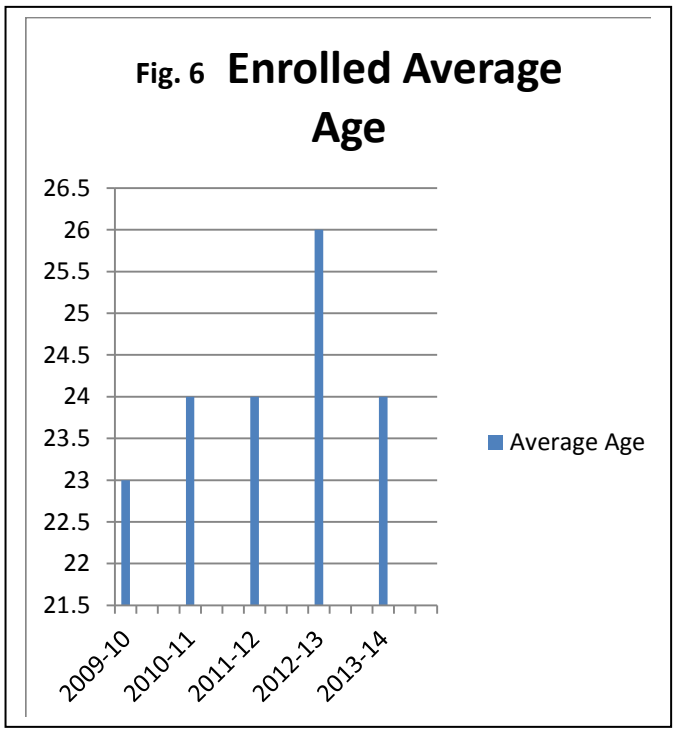


Fig. 6 Enrolled Average Age
26.5
26
25.5
25
24.5
24
23.5
23
22.5
22
21.5
2009-10
2010-11
2011-12
2012-13
2013-14
Average Age

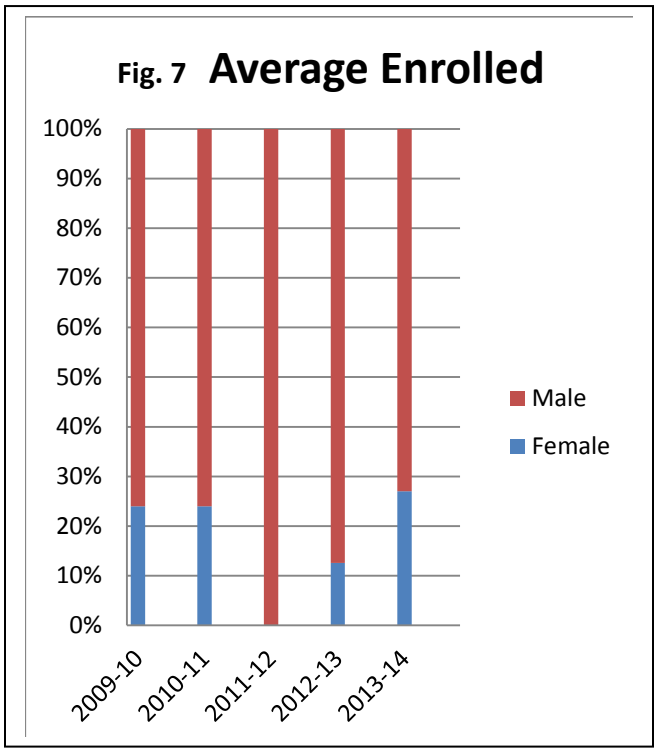


Fig. 7 Average Enrolled
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009-10
2010-11
2011-12
2012-13
2013-14
Male
Female

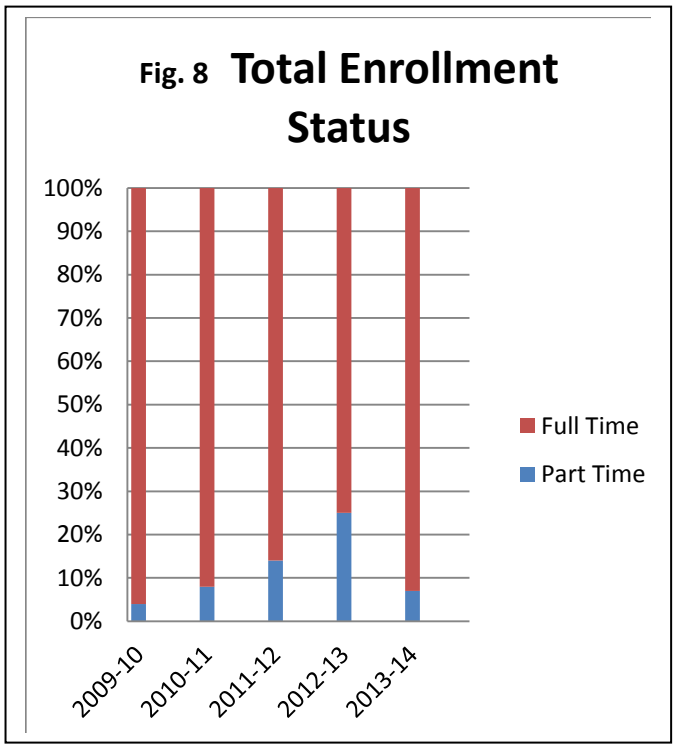


Fig. 8 Total Enrollment Status
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009-10
2010-11
2011-12
2012-13
2013-14
Full Time
Part Time

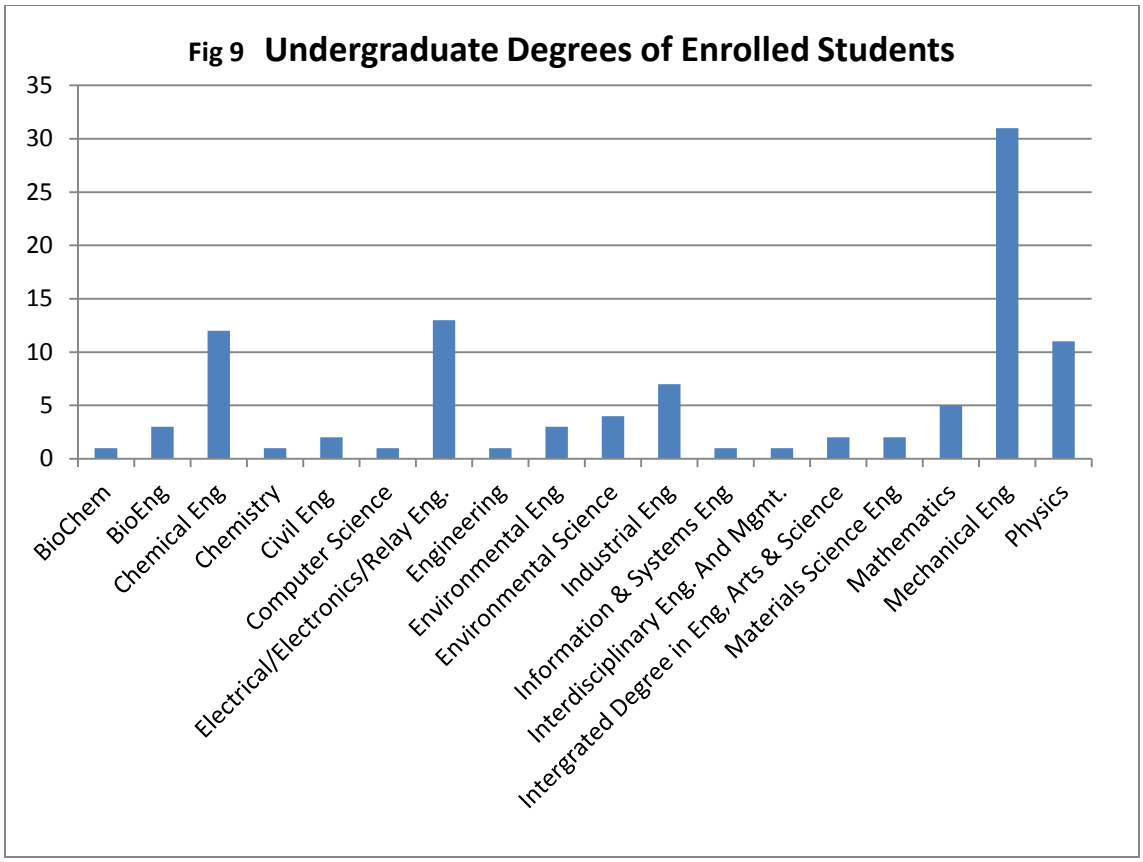


Table 1: List of Enrolled Student Undergraduate Degree Institutions (through May 2014)

Binghamton Univ.	Kalamazoo College	Univ. of Puerto Rico Maya
Boston College	National Univ. of Lesotho	University of Barcelona
Boston University	New Mexico Tech	Lehigh University (43)
Bucknell Univ.	NIT Rourkela - India	Kutztown Univ.
Cedar Crest College (2)	Penn State Kutztown	Lafayette College
Clarkson Univ.	Penn State Univ.	Lehigh University (43)
Columbus State University	Rutgers University	Messiah College
Cornell University	Salisbury University	Moscow Power Eng. Institute
Dalian University of Technology	San Diego State University	Nat. Univ. of Tainan, Taiwan
Duke Univ.	Shippensburg	University of Houston
East Stroudsburg University	SRM University	University of Houston
Franklin & Marshall	SUNY College of Environmental Science	University of MN, Morris
Galatasaray Univ. - Turkey	Technological Univ. of Panama	Villanova Univ.
High Nat'l School for Engrs Togo	The Mongolian Inst. of Science &Tech	Wayne State Univ.
Hong Kong Univ. Science & Tech	Trinity College	Westminster College
Islamic Azad University	Univ. of Hartford	Wilkes Univ.
K.J. Somaiya College of Eng.	Univ. of Pittsburgh	University of Houston

2. Student Productivity:
    a. The attrition rate for the program is 5% (4 of 81 enrolled students):

Table 2	Number of graduates	Attrition
2010	23	1 student left for personal reasons in the last semester
2011	22	none
2012	21	none
2013	11	3 students left program (2-MSME program; 1 personal reasons)
2014	18	None

    b. Program completion Rate:
    89 of the 95 students who graduated through 2014, or 94%, completed the program within 1 year.

    Six graduates completed the program in 1.5-2 years, due to:
    - Military service
    - Working full-time
    - Working part-time with a 9 credit semester workload

    c. Post Graduate Placement:
    ESEI has kept track of all but two of its 95 graduates. All 93 are employed or in Ph.D. programs, almost exclusively in energy fields.

    Several students have changed jobs since graduating, e.g. from one solar company to another, from one utility from another, or from one consulting firm to another.

    A few students in indirect energy related positions are working in positions such as an analyst for the Federal Reserve Bank, efficiency engineers for major transportation management systems, and technology consulting.

    Two students have parlayed their project management skills in areas outside energy. One student received a high paying offer as a project manager deploying electronic medical record systems. Before he accepted the position, he was concerned about "leaving" the energy arena, and talked about considering a change after two years. A second student, with very diverse interests is now a project manager for IT implementation and process improvements at World Wrestling Entertainment.

Table 3: List of Employers

Accenture (2)	GE Hitachi Nuclear Energy	Mercury Solar
Alcoa	Gehrlicher Solar	National Electr. Trans. Grid (Mongolia)
AK Energy Company Turkey	General Atomics	National Secretariat of Energy (Panama)
Ameresco	George Fischer	Navigant Consulting
BG&E (4)	Grant Thornton LLP	Nomac Services
Bonomo Turkish Taffy	Horizon Engineering Assoc.	Northeastern University
Burns & Roe	ECG Engineering	NVR, Inc.
Central Catholic High School	Energy and Resource Solutions	NYISO
Civic Solar	Exxon Mobil	OSI Software
Clever Devices	FERC	PECO (2)
Colonial Solutions	Federal Reserve Bank of Phila.	PEPCO
Colorado Springs Utilities	FLSmidth	PJM (2)
Con Edison of NY	Foster Wheeler	PPL (6)
Covanta Energy	Geatain Engineering	PSEG Nuclear
CSS Energy	GE Hitachi Nuclear Energy	RIT
Dept. of Veteran's Affairs	Gehrlicher Solar	RVM, Inc.
Dome-Tech/Noresco (2)	General Atomics	Safari Energy
Dresser-Rand	Grant Thornton LLP	Safe Bridge Solutions
DuPont (2)	Horizon Engineering Assoc.	Schneider Electric
Easton School District	IBM	Taiwan Surface Mount Tech
Ecotech Maine	KPMG Advisory	Tangent Energy
Exxon Mobil	Junell Corp	University of Lesotho
Electric Power Research Institute (EPRI)	Kupper Engineering	URS Corp.
FERC	Lehigh University – PhD (2)	US EPA
Federal Reserve Bank of Phila.	Lockheed Martin	Virginia Tech - PhD
FLSmidth	McGill University - PhD (2)	Voith Hydro
Foster Wheeler	Momentum Dynamics	WWE

B. Societal Relevance: Connection to Target Industries/Employers

1. Profile of Graduates:
    - As of May 2014, the M.Eng. Energy Systems Engineering program has graduated 95 students. Most students secured employment before graduation, however much of the information on timing is anecdotal.
    - Exit interviews conducted in 2012 indicated that 2/3 of the students had positions before graduation
    - The recent Alumni survey respondents indicated that 58% of students had positions before they graduated, and 80% of graduates had positions within three months.
    - All 93 of the 95 graduates with whom ESEI has contact information have positions.
    - ESEI uses LinkedIn and Facebook to connect and remain connected with students and graduates
    - With a few exceptions, all are energy industry companies hiring graduates (Table 3) or energy related positions within a company.

2. Employer Profile:
   The 95 graduates began their careers at 69 different companies, showing significant diversity in interests. Six companies have hired multiple graduates (Accenture, BG&E, Dupont, PECO, PJM and PPL Corp).
   See Table 3 above for a list of the employers of the ESEI graduates to date (some graduates have changed companies).

3. Industry advisory council membership:
   In the 2012-13 academic year, ESEI established regular meetings for individuals interested in formally forming the ESEI Strategic Advisory Council (SAC). In those meetings ESEI established and attendees agreed to the commitments required of SAC members.
   Commitment
   Attend 2 of 3 annual SAC meetings, and contribute in at least one of the following ways annually:
   - *Develop and sponsor a 2-semester industry project for ESE student(s)*
   - *Volunteer to provide technical lecture(s) for a seminar series at Lehigh, with the potential for CEU offering for professional engineers.*
   - *Provide financial support to ESE students, through program donations or "named" scholarships.*
   - *Donate new equipment for student and/or faculty research projects in areas such as smart grid communications and security.*

   The individuals in Table 4 have fulfilled the commitment to support ESEI, and will be established as the formal SAC at the October meeting. Terms will be determined at that meeting.

Table 4: ESEI Strategic Advisory Council

Dan	Chaply	Senior Trainer	PPL
Alexander	Chereskin	Engineer	PPL Generation, LLC
Bhavana	Keshavamurthy	Senior Engineer	PJM Interconnection
Marty	Matijasich	Managing Member and part Owner	Highlands Energy Group, LLC
Tsion	Messick	Power Systems Executive/Principal	Axum Energy Ventures
Dave	Nevius	VP NERC (retired)	NERC
Jim	Robinson	Sr Director	Relion Associates, LLC
David	Soyster	Supervising Engineer	PPL
Lou	Villani	Department Mgr - Project Engineering	Consolidated Edison
Andrew	Coleman	Manager, Environment & Renewables	EPRI

C. Operational Sustainability

1. Resource strength (faculty, staff, and facilities):

   Space (classrooms, research, offices for faculty and students) are excellent. The three spaces in the STEPS building (student study room, the adjunct/mentor office and the program offices) meet the needs of the program at this time. Laboratory/equipment has not been used in the program, though student comments request more hands on opportunities.
   Library and computer services meet the students' needs and the research assistance is excellent.

2. Program leadership sustainability

   The program has had administrative and leadership challenges in the first 4 years. In addition to a change in director and an interim director performing double duty in between, the program has had three different administrative coordinators in 4 years, requiring significant training and creating inefficiencies. With that period past, the leadership of the program should be sustainable for the foreseeable future.

3. Impact on rest of the Lehigh community:

   The ESE student interest areas are diverse enough that their impact on existing electives has not been a burden. The ME Advanced Energy Efficiency Practicum course is the only course with limited enrollment, and the Industrial Assessment Center (IAC approves all applicants.

   Industry advisors have been used as mentors for ESE students in recent years, in order to increase student connections with industry and as well as to not overburden Lehigh faculty. Lehigh faculty has provided support when a student's interest/project coincides with their own research and when they feel able to include it in their schedules for the duration of the project.

4. Academic relationships – the INE Cluster

   The Integrated Networks for Electricity (INE) research cluster was established at Lehigh in 2011 as a cross department and cross-College network of research collaborators.

   The INE research cluster has organized two very successful workshops:

   - Toward the Smart Grid (January 20, 2012)
   - Future Green Technologies: Challenges and Opportunities (Sept. 6, 2013)

   Various members have collaborated on several research proposals, resulting in increasing on-campus energy research initiatives that include faculty, PhD candidates, Masters and undergraduate students. For the Energy Systems Engineering program, Faculty/ESE relationships continue to expand with students supporting faculty research areas, connecting that student with both faculty and industry experts. In addition, ESE partnered with a faculty member on two PITA grants for projects involving ESE and PhD students.

Future Program Plans ("Self-evaluation of data")

A. Adjust purpose and positioning, if applicable.
The mission of the Master of Engineering in Energy Systems Engineering program is to invigorate the pipeline of new engineering graduates interested in energy oriented careers and thus produce a new generation of technical leaders for the energy and power industries. Over the next decade, nearly 50% of the skilled workers and technical leaders in the gas and electric utility industries will retire -- a much larger void than the current available and qualified professionals could fill. [CEWD, 2012 survey]

The mission statement continues to be valid and relevant. Energy remains a significant societal challenge from availability, economic and environmental aspects. The workforce continues to be disproportionately affected by "baby-boomer" retirements due to the past pattern of hiring with the growth and stagnation in the energy industry. In addition the growth in technology use and innovation in the industry requires more and new talents in its technical workforce.

In a study released by Northeastern University on September 17, 2013, conducted for them by FTI Consulting, the Key Findings support programs such as ESE that combine business knowledge, communication skills and experiential partnerships with industry. The Key Findings are:

"Key Findings

1. Americans continue to believe in the importance of higher education, but express concerns about the system's ability to prepare graduates for success in today's workforce.
2. Despite the recent focus on STEM degrees, most Americans and particularly business leaders say it is more important for graduates to be well-rounded and possess broader capabilities such as problem solving and communication skills.
3. Americans express declining confidence in online education, and they remain divided over the long-term benefits and impact of Massive Open Online Courses (MOOCs).
4. Americans resolutely believe in the importance of experiential learning for long-term career success.
5. Americans are divided on whether the greatest responsibility for preparing recent graduates for success lies with employers, colleges/universities or the graduates themselves."

http://www.northeastern.edu/innovationsurvey/pdfs/Northeastern_University_Innovation_Imperative_Higher_Ed_Outcomes_Poll_Deck_FINAL_Delivered.pdf

The challenge is in the implementation of the mission, as economic conditions have dramatically changed since the program was envisioned.

B. Identify plans for academic improvement:

Electives

Energy faculty and electives continue to grow, and the INE cluster faculty positions in Electrical & Computer Engineering, in Industrial & Systems Engineering, and in Economics have been filled. Faculty has created specific courses targeted at ESE from the beginning, with ECE 450 Communications Networks for Smart Grid being a particularly successful elective. One student review indicated this course should be a required elective for the program. The ME Renewable Energy and the new ME Advanced Energy Efficiency Practicum courses are also successful and relevant courses. Electives are directed to address the students' desires (new technology and environmentally sound resources) as well as employment opportunities (large energy employers and consulting in traditional companies).

Recently, a course in the Economics department on Advanced Electricity Economics has been a rigorous and relevant elective for several students. The course topics are usually taught as an engineering course in an institution with a power engineering course, and it would be useful if this course could be cross-listed as an ECE course.

In the last two years, significant time has been invested in counseling for individual Plans of Study for students, beginning in the first summer session. The discussion begins with an assessment of career goals and technical capabilities and career interests. Two to three sessions are usually required to set forth the fall semester plan, with an additional session or two to prepare for the spring (final) semester.

Faculty

The faculty in the Integrated Networks for Electricity (INE, or Smart Grid) cluster has increasing interest in partnering with the ESE program and students. In addition to the initial creation of electives, above, faculty has partnered on successful grant writing and joint projects, and the INE cluster has initiated a monthly seminars series which is very relevant to the students' studies. This trend will continue as faculty researchers continue to develop relevant partnerships with industry and utilize the intellectual capital of the students who can work with them on those projects.

A key intrinsic challenge at Lehigh is its lack of a power engineering program. Most Energy Systems masters programs have been developed at institutions with an undergraduate power systems programs, so the fundamental courses that some students desire are available. The INE cluster hires in the College of Business and Economics and the Industrial and Systems Engineering Department have been useful in expanding choices for students. The ECE cluster hire in 2014 has created an elective in Power Systems, which complements and expands the energy course offering focused on enabling a resilient grid that supports modern clean energy solutions.

C. Identify plans to improve the overall sustainability of the program, based upon weaknesses identified in the self-study.

Industry Project

In 2013-14, significant improvements have been made to the industry project course, and continued improvement is required. Project recruitment began earlier (in March), SAC members provided two projects for students, and thorough reviews with students regarding their project and career interests were conducted before agreeing on projects. However, more work is needed to:

- solicit and gather projects from diverse companies and diverse energy applications, particularly in the area of renewable energy and energy efficiency
- solidify the project scopes even earlier (although including students in the scope discussions is a valuable exercise)
- spend the time working with industry to help them create projects
- educate students about the goals of the project course
    - work on a real problem in a current industry field
    - work with industry professionals to meet deliverables
    - develop technical knowledge
    - enhance communication skills (written and verbal)
    - learn to develop and complete complex, unstructured projects and problems in the field of energy systems engineering

ESEI has implemented a structured approach to guiding student projects this fall, with weekly/bi-weekly report outs with their adviser, regular meetings with mentors, and specific mentor and sponsor guidelines, on which I will follow up regularly. Additional changes will be made as needed, and comments will be solicited in student exit interviews in April 2014.

Field Trips and "Hands-On" experiences

Students love the field trips, and would like even more. Many want "hands-on" work as well, indicating how much they value experiential learning. Field trips can be expensive and time-consuming, however, and laboratory or test-bed experiences on campus, in conjunction with the existing field trips, may be a more efficient way to meet this need.

We are currently investigating the potential for on-campus installation of equipment from at least two energy industry suppliers. The goal is to incorporate the facilities into existing electives, or into new electives. Funding, locations and teaching faculty will all need to be investigated as well.

Strategic Advisory Board

Additional time for targeting, contacting and meeting with the current and potential members would help to facilitate formalization and utilization of the SAC. Formal website presence will be incorporated in this academic year, with a formal newsletter, to meet the regular communications requested by the SAC.

Externships

The SAC survey results had a suggestion for externships, potentially for 1-2 weeks during the winter break. We will test that suggestion with the current cohort of students and with industry contacts.

Funding

Although the economy is improving, the electric energy industry is not freeing up disposable cash because of constraints caused by low and stagnant electric energy prices. ESEI is in the process of developing a second track, working with the Chemical Engineering Department, focused on the oil and gas industry that may be able to stimulate funding for the program and/or for student scholarships.

In addition, the implementation of hands-on elective courses, using vendor-donated equipment and addressing specific needs of the electric utility industry, may stimulate donations to fund the installation of the equipment. Conducting short-courses or industry training with the facilities (likely with adjunct faculty) could be an additional source of funding.

Recruiting

On campus sessions (technical presentation and program information) have been held at Gannon and Bucknell Universities, the Universities of Rhode Island and Massachusetts as well as Lafayette College, Saint John's University, Lehigh University, and Penn State University campuses... More work is needed in this area though.

- Presentations for at least 8 colleges/universities in the tri-state area
- Increase visibility and advertisement, and connection to Lehigh undergraduates through projects or courses are needed.

The Masters of Engineering in Energy System Engineering program provides an opportunity for cross-discipline education for graduates interested in a career in the energy industry. It focuses on electric power and the challenges and opportunities to develop a sustainable, reliable and resilient system that meets human needs in an increasingly sustainable manner through the use of environmentally sound energy resources and delivery. Both graduates and employers benefit from a well-trained professional workforce that is ready to hit the road running and be immediately productive in meeting these challenges, through this innovative and unique program.

Appendix 1

Technical Electives (12-15 credits)
Students acquire a level of specialized knowledge and experience through the completion of four to five technical elective courses, selected from a large pool of designated courses. Electives should reflect the student's career interest.
- Two (2) electives must be 400 level courses and
- Three (3) electives must be in the P.C. Rossin College of Engineering and Applied Science

Chemical Engineering
CHE 331 Separation Processes
CHE 350 Energy: Issues and Technology
CHE 373 Fundamentals of Air Pollution
CHE 400 Chemical Engineering Thermodynamics
CHE 410 Chemical Reaction Engineering
CHE 413 Heterogeneous Catalysis and Surface Characterization
CHE 415 Transport Processes
CHE 433 State Space Control
CHE 434 Multivariable Process Control
CHE 436 Systems Identification
Check with department for CHE 350/450 courses - Special Topics
Civil & Environmental Engineering
CEE 404 (Mech 404) Mechanics & Behavior of Structural Members
CEE 405 Analytical and Numerical Methods
CEE 406 Structural Reliability of Components and Systems
CEE 409 Finite Element Method in Structural Mechanics
CEE 412 Methodologies of Structural Design
CEE 414 Analysis and Design of Steel and Composite Structural Members
CEE 428 Environmental Groundwater Hydrology
CEE 431 Life-Cycle of Structural Systems (3)
CEE 452 Fatigue and Fracture of Structures - An Interdisciplinary View (3)
CEE 471 Environmental Risk Assessment (3)
CEE 475 Advanced Topics in Environmental Engineering (1-3)
Computer Science & Engineering
CSE 404 Computer Networks
CSE 341 Database Systems, Algorithms and Applications
CSE 441 Advanced Algorithms
CSE 443 Network Security
Electrical & Computer Engineering
ECE 308 Physics of Models of Electronic Devices
ECE 343 Digital Signal Processing
ECE 350 Power Electronics
ECE 361 Intro to VLSI Circuits
ECE 401 Advanced Computer Architecture

Appendix 1 (cont.)

ECE 402 Advanced Electromagnetic Theory
ECE 404 Computer Networks
ECE 411 Information Theory
ECE 420 Advanced Circuits & Systems
ECE 433 State Space Control
ECE 441 Fundamentals of Wireless Communications
ECE 450 Communication and Network for Smart Grids
ECE 450 Electrical Energy Systems
ECE 450 Intro to Photovoltaic Systems
ECE 450 Power Electronics
ECE 464 Introduction to Cryptography and Network Security
ECE 483 Advanced Semiconductor Devices for VLSI Circuits
Check with department for ECE 350/450 courses - Special Topics
Industrial & Systems Engineering
IE 339 Stochastic Models and Application
IE 358 Game Theory
IE 382 Leadership Development
IE 404 Simulation
IE 409 Time Series Analysis
IE 419 Planning and Scheduling
IE 426 Optimization Models and Applications
IE 447 Financial Optimization
IE 458 Topics in Game Theory
IE 460 Engineering Project
Materials Science & Engineering
MAT 314 Metal Forming Processes
MAT 315 Physical Properties of Structural and Electronic Ceramics
MAT 344 Metal Machining Analysis
MAT 346 Physical Metallurgy of Welding
MAT 348 Materials Science for Electronic Applications
MAT 393 Physical Polymer Science
MAT 403 Structure and Properties of Materials
MAT 455 Materials for Nanotechnology
Check with department for MAT 409 course - Current Topics in Materials
Mechanical Engineering & Mechanics
ME 322 Gas Dynamics
ME 360 Nuclear Reactor Engineering
ME 362 Nuclear Fusion and Radiation
ME 364 Renewable Energy
ME 366 Clean Coal Technology
ME 376 Energy: Issues and Technology
ME 402 Advanced Manufacturing Science

Appendix 1 (cont.)

ME 413 Numerical Methods in Mechanical Engineering
ME 420 Advanced Thermodynamics
ME 423 Heat and Mass Transfer
ME 424 Unsteady and Turbulent Flow
ME 426 Radiative and Conductive Heat Transfer
ME 430 Advanced Fluid Mechanics
ME 431 Advanced Gas Dynamics
ME 433 State Space Control
ME 444 Experimental Stress Analysis in Design
ME 446 Mechanical Reliability
ME 450 Advanced Numerical Methods
ME 452 Mathematical Methods in Engineering I
ME 453 Mathematical Methods in Engineering II
ME 468 Advanced Energy Efficiency Practicum
ME 485 Polymer Processing

MECH 404 Mechanics & Behaviors of Structural Members
MECH 406 Fundamentals of Solid Mechanics
MECH 413 Fracture Mechanics
MECH 425 Analytical Methods in Dynamics
Business and Science - (1-2 electives allowed)
Chemistry
CHM 312 Fundamentals of Corrosion
CHM 342 Thermodynamics and Kinetics
CHM 441 Chemical Kinetics
CHM 443 Solid State Chemistry
Earth & Environmental Science
EES 306 Geological Records of Environmental Change
EES 334 Geosphere Structure and Evolution
EES 358 Microbial Ecology
EES 402 Environmental Scientific Foundation for Policy Design
EES 407 Seismology
EES 415 Paleoclimatology
EES 426 Tectonic Processes
EES 427 Organic Belts
EES 457 Advanced Remote Sensing of the Environment
EES 459 Reconstructing Environmental Change

Economics

ECO 454 Economics of Environmental Management
ECO 311 Environmental Economics ECO 456 Industrial Organization

Appendix 1 (cont.)

ECO 480 Economics of Technological Change
ECO 497 Advance Electricity Economics
Check with department for ECO 492 courses - Special Topics
Environmental Studies
ES 328 U.S. Politics and the Environment
ES 339 Global Security and the Environment
ES 402 Scientific Foundations for Environmental Policy Design
ES 431 US Environmental Law
ES 433 International Environmental Law & Policy
ES 438 Environmental Risks: Perception & Communication
ES 496 (POLS 496) Global Energy Policy & Politics
International Relations
IR 333 International Environmental Law and Policy
IR 339 Global Security and the Environment
IR 340 International Environmental and Science Policy
IR 344 International Politics of Oil
Physics
PHY 348 Plasma Physics
PHY 362 Atomic and Molecular Structure
PHY 363 Physics of Solids
PHY 364 Nuclear and Elementary Particle Physics
PHY 420 Mechanics
PHY 421 Electricity & Magnetism I
PHY 422 Electricity & Magnetism II
Check with department for PHY 472 courses - Special Topics
Political Science

POLS 355/455 Environmental Justice and the Law
POLS 416 American Environmental Policy
POLS 475 Seminar: Green Policy
POLS 496 (ES 496) Global Energy Policy & Politics
Check with department for POLS 481/482 Courses - Special Topics