EST&P Applied Studies pre-approved project courses

(that satisfy requirements towards 24 units of project coursework)
DRAFT version 2.0 – August 11, 2017

Please note: Courses may not be offered every year, and space is not guaranteed in any specific class or section. If you wish to petition for a course not on this list to count towards project requirements, please contact your academic advisor. A project intensive course is defined by a College of Engineering course with at least a minimum of 30% of the course grade is from project work (individual or group) and faculty review or approval.

Following this Table are individual course descriptions, as of the time this document was written. A list of independent study courses for EST&P and partner departments appears at the end of the document. This is to be used in conjunction with the EST&P Master's Project Approval form (found on Canvas).

Course Number	Course Title	Number of Units	Term Typically Offered	Recommended Background
39-605	Engineering Design Projects	12	Fall	All
39-606	Engineering Design Projects	12	Spring	All
TBD	Engineering Optical and Thermal Energy Transport: Energy Efficiency Applications of Optical Coatings	12	Spring	MSE, MEG, ECE and CHE
12-706	Civil Systems Investment Planning and Pricing	12	Fall	All
12-718	Environmental Engineering, Sustainability and Science Project	12	Spring	CEE
12-745	Advanced Infrastructure Systems Project	12	Spring	CEE
12-761	Sensing & Data Mining in Smart Structures and Systems	12	Spring	CEE, ECE
18-500* *undergraduate units*	ECE Design Experience	12	Fall	ECE
18-743	Energy Aware Computing	12	Fall	ECE
10-601 or 10-701 *must be project section	Introduction to Machine Learning	12	Fall and Spring	ECE *see course description for prerequisites

24-618	Computational Analysis of Transport Phenomena	12	Spring	MEG
24-642	Fuel Cell Systems	12	Fall	MEG, MSE, CHE * *Thermodynamics prerequisite
24-643	Special Topics: Electrochemical Energy Storage Systems	12	Fall	MEG, MSE, CHE, ECE
24-645	Air Pollutant Sensor Design and Application	12	Spring	MEG, ECE
24-646	Special Topics: Energy Technology Environmental Control Systems	12	Fall	MEG, CEE, CHE, MSE
24-722	Energy Systems Modeling	12	Fall	MEG, MSE, CHE * *Thermodynamics prerequisite
24-778	Mechatronic Design	12	Spring	MEG, ECE
19-451* *Only specific terms and under specific circumstances	EPP Projects	12	Spring	EPP
19-686	New Technology Commercialization: Public Policy Strategies	12	Spring	All

Course Descriptions

<u>39-605 (Fall) and 39-606 (Spring) Engineering Design Projects</u>
In this project course, students work in multidisciplinary teams to design products or processes. The course is open to juniors, seniors and graduate students from all parts of the campus community. Each project is sponsored by an industry, government or non-profit partner, and is of real commercial interest to that partner. Students work directly with their partner throughout the semester to establish goals and requirements, evaluate their design as it progresses, and produce a final report, presentation, and, if appropriate, a prototype. Design reviews, held twice during the semester, give students a chance to present their preliminary designs and receive feedback and advice. In completing their designs, teams must consider not only the functionality of their designs, but also the look, feel, appearance, and societal impact. Skills built in this course will include: developing the product statement, establishing goals and constraints for the product, project management, and generating and evaluating design alternatives. As some projects may span multiple semesters with new groups of students, careful documentation of project work is emphasized. Students may take this course for either one or two semesters.

TBD   Engineering Optical and Thermal Energy Transport: Energy Efficiency Applications of Optical Coatings
TBA

12-706 Civil Systems Investment Planning and Pricing
This course introduces students to the fundamental principles and quantitative methods used in engineering systems, and how to communicate results. Its primary audience is first year graduate students in engineering. The course covers economic-based decision making methods, such as decision trees, benefit-cost and cost-effectiveness analysis, and more advanced decision and risk analysis methods like sensitivity analysis, multi-attribute, and simulation. The integration of uncertainty into formal methods is a fundamental component of the course, and tells us how confident we should be in our answers. The primary applications in this course will deal with infrastructure systems planning and environmental policy.

12-718 Environmental Engineering, Sustainability and Science Project
This course integrates and exercises students in a significant sustainable engineering and/or environmental project that is team-based and built upon the knowledge, skills, and technologies learned in the core and specialist courses in the EESS graduate curriculum.

12-745 Advanced Infrastructure Systems Project

This course will integrate and exercise students in a significant AIS system development project that is team-based, related to some area of infrastructure systems, industry driven, and built upon the knowledge, skills, and technologies learned in the core and specialist courses in the AIS program.

12-761 Sensing & Data Mining in Smart Structures and Systems
This course will introduce smart monitoring systems for applications in physical structures and systems. Such monitoring systems enable us to understand the performance of the physical systems and diagnose/prognose their critical status using technologies, such as sensor network and data analytics. Examples include but not limited to structural health monitoring, traffic monitoring, water/air quality sensing, patient monitoring, etc. The goal is for students to understand the overall process from obtaining data to specific application performance in a systematic way. This course is intended for graduate students with prior exposure to probability, statistics, computer programming, and physical science.

18-500 ECE Design Experience*
*undergraduate units
The ECE Design Experience is a capstone design course that serves to introduce students to broad-based, practical engineering design and applications through an open-ended design problem. Students will work with a team on a project of their choosing (subject to instructor approval) throughout the semester culminating with a final project presentation, report, and public demonstration. The projects will need to encompass a minimum of two ECE areas. Throughout the semester, teams will need to give both written and oral project proposals and periodic performance updates. Team-building experiences designed to educate students on group dynamics, resource management, deadline planning, Big-picture implications of engineering applications: societal, human, ethical, and long-term impact will be explored.

18-743 Energy Aware Computing
This course provides a comprehensive coverage of topics related to energy aware and green computing. While it is widely recognized that power consumption has become the limiting factor in keeping up with increasing performance trends, static or point solutions for power reduction are beginning to reach their

limits. This course is intended to provide an insight into: (i) power and energy consumption modeling and analysis; (ii) energy aware computing, i.e., how various power reduction techniques can be used and orchestrated such that the best performance can be achieved within a given power budget, or the best power efficiency can be obtained under prescribed performance constraints; and (iii) green computing in the context of large scale computing systems or smart grid-aware computing. Recommended: basic VLSI design, basic computer system organization, basic compiler design and OS knowledge. Prerequisites: Senior or Graduate Standing.

10-601 Introduction to Machine Learning (Masters)*
*10-701 is also acceptable
Machine Learning (ML) develops computer programs that automatically improve their performance through experience. This includes learning many types of tasks based on many types of experience, e.g. spotting high-risk medical patients, recognizing speech, classifying text documents, detecting credit card fraud, or driving autonomous vehicles. 10601 covers all or most of: concept learning, decision trees, neural networks, linear learning, active learning, estimation the bias-variance tradeoff, hypothesis testing, Bayesian learning, the MDL principle, the Gibbs classifier, Naive Bayes, Bayes Nets Graphical Models, the EM algorithm, Hidden Markov Models, K-Nearest-Neighbors and nonparametric learning, reinforcement learning, bagging, boosting and discriminative training. Grading will be based on weekly or biweekly assignments (written and/or programming), a midterm, a final exam, and possibly a project (details may vary depending on the section). 10601 is recommended for CS Seniors Juniors, quantitative Masters students, non-MLD PhD students. Prerequisites (strictly enforced): strong quantitative aptitude, college probstats course, and programming proficiency. For learning to apply ML practically effectively, without the above prerequisites, consider 11344/05834 instead. If you are unsure whether you have sufficient mathematical background to do well in this course, you should consider taking the mini 10-600 Mathematical Background for Machine Learning. You can evaluate your ability to take the course via a self-assessment exam at: https://qna-app.appspot.com/view.html?aglzfnFuYS1hcHByGQsSDFF1ZXN0aW9uTGlzdBiAgICgpO-KCgw
ML course comparison: https://docs.google.com/document/d/1Y0Jx_tcINWQrWJx31WGEQSsUs059OUMmPIVSeyxNdeM/edit

24-618 Computational Analysis of Transport Phenomena
In this course, students will develop basic understanding and skill sets to perform simulations of transport phenomena (mass, momentum, and energy transport) for engineering applications using a CAE tool, learn to analyze and compare simulation results with theory or available data, and develop ability to relate numerical predictions to behavior of governing equations and the underlying physical system. First 8 weeks of the course will include lectures and simulation-based homework assignments. During last 7 weeks, teams of students will work on self-proposed projects related to computational analysis of transport phenomena. In the project, students will learn to approach loosely defined problems through design of adequate computational mesh, choice of appropriate numerical scheme and boundary conditions, selection of suitable physical models, efficient utilization of available computational resources etc. Each team will communicate results of their project through multiple oral presentations and a final written report.

24-642 Fuel Cell Systems
Fuel cells are devices that convert chemical potential energy directly into electrical energy. Existing fuel cell applications range from the small scale, such as portable cell phone chargers, to the large scale, such as MW-scale power plants. Depending on the application, fuel cell systems offer unique advantages and disadvantages compared with competing technologies. For vehicle applications, they offer efficiency and environmental advantages compared with traditional combustion engines. In the first half of the course, the focus is on understanding the thermodynamics and electrochemistry of the various types of fuel cells, such as calculating the open circuit voltage and the sources of voltage loss due to irreversible processes for the main fuel cells types: PEM/SOFC/MCFC. The design and

operation of several real fuel cells are then compared against this theoretical background. The second half of the course focuses on the balance-of-plant requirements of fuel cell systems, such as heat exchangers, pumps, fuel processors, compressors, as well as focusing on capital cost estimating. Applying the material learned from the first and second halves of the class into a final project, students will complete an energy economic analysis of a fuel cell system of their choice. Prerequisite- Undergraduate Thermodynamics course 12 units

24-643 Special Topics: Electrochemical Energy Storage Systems
Contemporary energy needs require large scale electrochemical energy conversion and storage systems. Batteries are playing a prominent role in portable electronics and electric vehicles. This course introduces principles and mathematical models of electrochemical energy conversion and storage. Students will study thermodynamics, reaction kinetics pertaining to electrochemical reactions, phase transformations relating to batteries. This course includes applications to batteries, fuel cells, supercapacitors

24-645 Air Pollutant Sensor Design and Application
In this course, students will be instructed in the development, testing, and deployment of air quality monitoring networks. Key topics will include: introduction to EPA regulations for air pollutants and the measurements used to monitor compliance with those regulations; operating principles behind standard EPA measurements and emerging sensors; emissions of pollutants; effects of pollutants on human health and climate; sensor calibration and maintenance; data collection, processing, and interpretation. Statistical treatment of data will also be discussed. A major focus of this class will be a team-based project, in which students design, construct, and deploy small, low-cost air pollutant sensors. The course assumes understanding of thermodynamics, basic chemistry, and computer programming.

24-646 Special Topics: Energy Technology Environmental Control Systems
A critical component of energy technology design and operation is the control of environmental emissions. This course will cover the design basics of technologies used to control air and water pollution from energy conversion processes, such as power plants and industries. Technologies such as scrubbers, catalytic processes, precipitators, membranes etc will be designed. Relevant concepts from thermodynamics, mass and energy balances, mass and heat transfer and chemical reaction equilibrium and kinetics are covered. Through assignments and projects, the students will design individual pollution control technologies and then analyze their feasibility when integrated into specific applications. Preliminary cost assessment modeling will also be introduced.

24-722 Energy System Modeling
This course focuses on the thermodynamic modeling of energy systems with emphasis on energy/availability analysis techniques. These techniques are developed and applied to both established and emerging energy technologies, such as internal combustion engines, gas- and coal-fired power plants, solar and wind energy systems, thermochemical hydrogen production cycles, and fuel cells. The course will also consider the integration of components such as reformers and electrolyzers. Modern computational tools are used throughout the course. The course culminates with a group project that requires developing sophisticated, quantitative models of an integrated energy system. Students are expected to have completed an undergraduate course in thermodynamics comparable to 24-221. (12 units) 4 hrs lec. Pre-requisite: 24-221 or 06-221 or 27-215, or equivalent

24-778 Mechatronic Design
Mechatronics is the synergistic integration of mechanical mechanisms, electronics, and computer control to achieve a functional system. Because of the emphasis upon integration, this course will center around laboratory projects in which small teams of students will configure, design, and implement

mechatronic systems. Lectures will complement the laboratory experience with operational principles and system design issues associated with the spectrum of mechanical, electrical, and microcontroller components. Class lectures will cover selected topics including mechatronic design methodologies, system modeling, mechanical components, sensor and I/O interfacing, motor control, and microcontroller basics.

19-451 EPP Projects*
*Only specific terms and under specific circumstances
Interdisciplinary problem-solving projects in which students work as leaders or members of project teams. Problem areas are abstracted from local, state and national situations and involve the interaction of technology and public policy, with different projects being chosen each semester. Oral and written presentations concerning the results of project studies are required.

19-686 Special Topics: New Technology Commercialization: Public Policy Strategies
During this project-based class, students will develop non-market strategies for real-world clients. As defined, by David Baron, "The nonmarket environment consists of the social, political, and legal arrangements that structure interactions among companies and their public." This class will focus on non-market strategies at the intersection of new technologies, public policies, and business. Entrepreneurs and innovators interested in commercializing technology in the biomedical, energy, transportation, information technology, robotics, aerospace, food, healthcare, and other industries require more than knowing whether a technology works and the potential market. Non-market factors such as regulations, standards, and grants influence product, price, location, research, development, and testing, and other decisions. As a result, public policies provide both opportunities and challenges for the commercialization of an invention. Only by recognizing these opportunities or overcoming these challenges can an invention become a commercialized innovation.

Independent Project Work

For an EST&P student who desires a project or research-like experience outside a classic classroom structure, he or she must find an **engineering faculty member** who is willing and able to supervise an appropriate sized and scoped project related to energy. Other CMU faculty whose research area is focused on energy may be approved on a case by case exception basis. Project topics are self-defined working in cooperation with an engineering faculty member; they are NOT assigned by the EST&P program. Project course units must be taken for a letter grade to count towards degree requirements and to fulfill the project units for the Applied Studies degree. Any combination of 24 units of 39-660 or equivalent course units will fulfill the project requirement. Summer internship project units, such as those taken for CPT, will also count towards this degree requirement. Ideally the project topic will be related to, and increase preparation for, a student's professional and career goals.

Instructions for one-on-one faculty supervision

Below are some recommended steps to guide you towards an independent project process. However, they do not guarantee success:
1. Identify a faculty member, with whom you might want to do project work. Sources are: an engineering professor teaching one of your classes, faculty associated with either the EST&P program or the Scott Institute for Energy Innovation, or identifying a topic area that a faculty member has expertise. Website listing of associated EST&P faculty: http://www.cmu.edu/engineering/estp/about-us/faculty-and-staff.html

2. Narrow down the list, and contact a few faculty members. This can be before or after class, during their office hours, or a very concise and politely worded email of introduction. Also, before meeting with faculty consider talking with their PhD students to learn about the detailed work going on within their faculty advisor's research group.
3. Discuss areas of common interest, and highlight what skills and background you can offer to the professor's focus area or research projects. Also discuss possible final deliverables for the project work, such as poster, contributions towards a paper, develop a model, etc.
4. After the supervising faculty member agrees to supervise your independent project, scope out the subject area, deliverables, and number of units that reflects this amount of work.
5. The student then fills out the EST&P master's project approval form (or similar type of document from the faculty member's home department), have the supervising faculty member sign it, and then turn it in to the EST&P office for EST&P advisor approval.
6. Once approved, register in SIO for the appropriate number of units (either 39-660 course or a similar corresponding course number in the supervising faculty member's department). The number of units should correlate with the amount of work to be performed. The project work requires a letter grade to be assigned at the end of each semester. The number of units registered for is variable, although it is typically in increments of 3 units: 3, 6, 9 or 12 units.

Course Number	Course Title	Number of Units	Term Typically Offered	Recommended Background
39-660 (preferred)	Masters EST&P Project	Variable Based on scope of project work	Fall and Spring	All
06-660	Masters Chemical Engineering Project	Variable Based on scope of project work	Fall and Spring	CHE
12-792	Advanced Independent Study	Variable Based on scope of project work	Fall and Spring	CEE
18-980	M.S. Graduate Project	Variable Based on scope of project work	Fall and Spring	ECE
19-700	Directed Study in EPP: Graduate	Variable Based on scope of project work	Fall and Spring	EPP
24-794	Master of Science Project	Variable Based on scope of project work	Fall and Spring	MEG
27-756	Masters Project	Variable Based on scope of project work	Fall and Spring	MSE

Course Descriptions

39-660 Masters EST&P Project
This project course is designed for EST&P students who are working on an independent investigation on a project related to energy with the advice and approval of the program advisor and/or affiliated faculty member. Summary report, presentation or poster on work accomplished must be submitted at completion of semester. Once you have determined a suitable topic area, found an engineering faculty member who has agreed to supervise the project work, send the EST&P project approval form to the EST&P director for enrollment. Variable units. Restricted to EST&P students

06-600 Masters Chemical Engineering Project
No course description.

12-792 Advanced Independent Study
In-Depth investigation of selected advanced topics not offered in formal courses. By special arrangement upon demand and with approval of the instructor. Prerequisites: Permission of instructor.

18-980 M.S. Graduate Project
No course description.

19-700 Directed Study in EPP: Graduate
No course description.

24-794 Master of Science Project
This course is designed to be a training opportunity in engineering research and associated professional activity. Content includes a series of investigations under the student's initiative culminating in comprehensive reports, with special emphasis on orderly presentation and effective English composition for Master of Science candidates. Variable hrs. Prerequisite: permission of the instructor.

27-756 Masters Project
Individual research project, including laboratory, theoretical, library or design work followed by a written or oral report on the work accomplished.