ENERGY (ENGY)

ENGY198. SPECIAL TOPICS. 1-6 Semester Hr.
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

ENGY200. INTRODUCTION TO ENERGY. 3.0 Semester Hrs.
Introduction to Energy. Survey of human-produced energy technologies including steam, hydro, fossil (petroleum, coal, and unconventionals), geothermal, wind, solar, biofuels, nuclear, and fuel cells. Current and possible future energy transmission and efficiency. Evaluation of different energy sources in terms of a feasibility matrix of technical, economic, environmental, and political aspects. 3 hours lecture; 3 semester hours.

ENGY298. SPECIAL TOPICS. 1-6 Semester Hr.
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

ENGY310. INTRO TO FOSSIL ENERGY. 3.0 Semester Hrs.
Students will learn about conventional coal, oil, and gas energy sources across the full course of exploitation, from their geologic origin, through discovery, extraction, processing, processing, marketing, and finally to their end-use in society. Students will be introduced to the key technical concepts of flow through rock, the geothermal temperature and pressure gradients, hydrostatics, and structural statics as needed to understand the key technical challenges of mining, drilling, and production. Students will then be introduced to unconventional (emerging) fossil-based resources, noting the key drivers and hurdles associated with their development. Students will learn to quantify the societal cost and benefits of each fossil resource across the full course of exploitation and in a final project will propose or evaluate a national or global fossil energy strategy, supporting their arguments with quantitative technical analysis. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- no change

ENGY320. INTRO TO RENEWABLE ENERGY. 3.0 Semester Hrs.
Survey of renewable sources of energy. The basic science behind renewable forms of energy production, technologies for renewable energy storage, distribution, and utilization, production of alternative fuels, intermittency, natural resource utilization, efficiency and cost analysis and environmental impact. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- no change

ENGY340. NUCLEAR ENERGY. 3.0 Semester Hrs.
Survey of nuclear energy and the nuclear fuel cycle including the basic principles of nuclear fission and an introduction to basic nuclear reactor design and operation. Nuclear fuel, uranium resources, distribution, and fuel fabrication, conversion and breeding. Nuclear safety, nuclear waste, nuclear weapons and proliferation as well economic, environmental and political impacts of nuclear energy. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- no change

ENGY350. GEOTHERMAL ENERGY. 3.0 Semester Hrs.
Geothermal energy resources and their utilization, based on geoscience and engineering perspectives. Geoscience topics include world wide occurrences of resources and their classification, heat and mass transfer, geothermal reservoirs, hydrothermal geochemistry, exploration methods, and resource assessment. Engineering topics include thermodynamics of water, power cycles, electricity generation, drilling and well measurements, reservoir-surface engineering, and direct utilization. Economic and environmental considerations and case studies are also presented. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- no change

ENGY398. SPECIAL TOPICS. 6.0 Semester Hrs.
Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

ENGY399. INDEPENDENT STUDY. 0.5-6 Semester Hr.
Students can do individual research or special problem projects supervised by a faculty member. The student and instructor will agree on the subject matter, content, and credit hours.

ENGY419. THE PRINCIPLES OF SOLAR ENERGY SYSTEMS. 3.0 Semester Hrs.
Overview of the solar resource and components of solar irradiance; principles of photovoltaic devices and photovoltaic system design; photovoltaic electrical energy production and cost analysis of photovoltaic systems relative to fossil fuel alternatives; introduction to concentrated photovoltaic systems and manufacturing methods for wafer-based and thin film photovoltaic panels. 3 hours lecture; 3 semester hours. Prerequisite: PHGN200; MATH225.
Course Learning Outcomes

- Calculate Solar Resources
- Understand Solar Devices
- Derive Photovoltaic Effects
- Compare Economics of Solar
- Conceptualize Concentrated Solar
- Design Solar Manufacturing

ENGY475. INTRODUCTION TO NUCLEAR ENGINEERING. 3.0 Semester Hrs.
An overview of major concepts and themes of nuclear engineering founded on the fundamental properties of the neutron, and emphasizing the nuclear physics bases of nuclear reactor design and its relationship to nuclear engineering problems. Major topics that introduce fundamental concepts in nuclear engineering include the physics and chemistry of radioactive decay, radiation detection, neutron physics, heat transfer in nuclear reactors, and health physics. Nuclear engineering topics relevant to current events are also introduced including nuclear weapons, nuclear proliferation, and nuclear medicine. Prerequisite: MATH225, PHGN200.
Course Learning Outcomes

- 1) Apply concepts of radioactivity to solve problems
- 2) Relate neutron production and consumption to aspects of the lifecycle of the nuclear fuel and nuclear power production
- 3) Apply the basics of nuclear reactor physics and heat transfer to reactor design and operation

- 4) Understand the biological effects of radiation and use basic radiation shielding equations

ENGY499. INDEPENDENT STUDY. 0.5-6 Semester Hr.
Students can do individual research or special problem projects supervised by a faculty member. The student and instructor will agree on the subject matter, content, and credit hours.

ENGY501. PHYSICS OF ENERGY RESOURCES & CONVERSION. 3.0 Semester Hrs.
This course will provide successful students a quantitative understanding of how fossil, renewable and nuclear energy resources are harnessed to electric power. A foundational underpinning will be the thermodynamics of energy conversion, using fundamental principles and language bridging physics, chemistry and engineering. Examples will be taken from both established and emerging technologies spanning solar, nuclear, wind fossil fuel and bioenergy conversion. Students will also learn how to analyze electricity generation, transmission, and grid-scale storage systems with a focus on the U.S. as a framework for analyzing other developing markets.
Course Learning Outcomes

- With respect to all energy resources: 1. Articulate in writing, major quantitative trends and forces behind the evolution of fossil, nuclear, and renewable energy resource utilization of the U.S.; 2. Demonstrate knowledge of how permitting, regulations, markets, and environmental impact drive investment for utility-scale power generation; 3. Compare quantitatively the levelized cost of electricity, major environmental impacts, and water usage for electricity generation from fossil, renewable, and nuclear resources;
- With respect to solar resources: 4. Quantitatively assess solar resources in the U.S. and the challenges (economic and grid-related) to increase solar penetration on the electric grid; 5. Quantify advances in solar photovoltaic technology in terms of cost and efficiency and estimate trends for levelized costs of electricity for photovoltaics over the next 10 years; 6. Evaluate levelized cost of electricity for concentrating solar power with thermal energy storage for utility scale applications;
- With respect to wind, geothermal, and hydroelectric resources 7. Quantitatively assess wind, geothermal, and hydropower resources in the U.S. and opportunities for increased penetration in the electric utility grid; 8. Perform basic analysis of levelized cost of electricity as a function of wind conditions, turbine size, and turbine location based on weather conditions;
- With respect to biomass resources 9. Compare different biomass resources for fuels and power plants and their economic viability relative to other fuel and power resources;
- With respect to fossil fuel resources: 10. Demonstrate quantitative knowledge of coal and natural gas extraction from an unconventional reservoir and evaluate costs of extraction and delivery of fossil fuel resources; 11. Analyze basic thermodynamic performance and operation of present-day Rankine, Brayton, and combined cycle power plants running on fossil fuel inputs including coal;
- With respect to nuclear resources: 12. Demonstrate basic knowledge of differences in the major nuclear power plant technologies in terms of conversion efficiencies and waste streams;
- With respect to the current utility-scale electric grid: 13. Evaluate the cost and performance of power generation sources and grid-scale storage technology and assess the impact on energy markets and renewable energy penetration; 14. Assess the impact of storage on transition of the US power system and future research and development needs; 15. Perform real-time electricity pricing calculation for a selected electricity market in U.S.;
- With respect to advanced energy grids, distributed power, and energy storage: 16. Articulate advances in distributed power and advanced controls and their impact upon grid operation and utility markets in a smart grid framework for the U.S.; 17. Identify the challenges and risks arises due to cyber-security in a smart grid and articulate awareness of the essential tools used to secure grid infrastructure; 18. Evaluate energy storage technologies and compare their economic feasibility, round-trip efficiency, and potential capacity for distributed power applications.

ENGY502. ENERGY FOR TRANSPORTATION. 3.0 Semester Hrs.
(I) This course focuses on multiple aspects of current and proposed transportation technologies to analyze the challenges and opportunities of moving toward more sustainable transportation infrastructure. This course is designed to train students to develop analytical skills and to use computational tools for evaluating performance and environmental impacts of various vehicle and fueling technologies. Successful students will develop a basis for assessing energy resource requirements and environmental concerns within the context of technical performance, policy frameworks, and social perspectives. The course will include the following topics: travel demand and travel modes; transportation technologies; fossil-fuel and electric power plants and associated fuels; emissions (CO_2 and pollutants) formation and impacts on air quality, climate, and human health; national/international transportation policy; and transportation planning. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- With respect to the oil and gas distribution systems: 1. Perform assessment on the oil and natural gas distribution network in terms of sensitivity of fuel prices to key economic, environmental and political factors; 2. Evaluate the midstream and downstream production of U.S. liquid fuels; 3. Articulate the risks associate with fossil fuel production and utilization and the associated environmental impacts; 4. Assess the impact of vehicle electrification on oil and gas markets;
- With respect to aerospace and shipping transportation and fuels: 5. Assess the efficiency of all types of vehicle transportation technology and major historical trends with respect to fuel demands for various transportation sectors; 6. Identify fuel(s) needed for aircraft propulsion and assess trends for efficiency and reduced emissions from large aircraft; 7. Assess fuel utilization for large-scale shipping of goods with ships, trains, and large trucks and evaluate potential paradigm shifts in heavy transportation; 8. Perform well-to-wheel analysis on at least two large-vehicle technology platforms and assess the feasibility of alternative fuel sources and/or energy carriers;
- With respect to automotive transportation, fuels, and alternative energy carriers: 9. Assess internal combustion engine technology performance and emissions from a historical perspective and with respect to current-day trends; 10. Evaluate electric vehicle performance including battery and charging technologies including with respect to costs and energy demands for selected transportation sectors; 11. Articulate opportunities and challenges of a hydrogen- or biomass/waste gasification to support fueling infrastructure for a region of the U.S.; 12. Perform well-to-wheel analysis on at least two automotive technology platforms and assess their impact on energy usage and emissions; 13. Conduct technoeconomic analysis of hydrogen as an energy carrier for the transportation sector and the potential for fuel cells in vehicles; 14. Identify the challenges and risks arises due to cyber-security in an electrified transportation system, including autonomous systems.

ENGY503. ENERGY & POWER SYSTEMS INTEGRATION. 3.0 Semester Hrs.

This course will provide students with basic skills to analyze the operation and evolution of the electric grid and electricity utilization with a particular emphasis on trends toward increased renewable energy penetration. The course will develop students' analytical skills to evaluate how electricity generation, transmission, distribution and storage are managed and controlled. Successful students will gain a basic understanding of electromechanical machines for power conversion and AC power distribution as well as renewable energy sources and battery systems with DC storage. The course will introduce students to how efficient energy utilization and demand response management impact the electric grid performance and electricity markets. An emphasis on managing energy loads in buildings, the commercial sector, and energy-intensive manufacturing will expose students to system-level modeling tools that can assess how to manage power demands with transient power generation and market forces. The course will also address the integrated nature of energy systems with an emphases on connections to water demands and on risks arising due to cybersecurity and resiliency threats facing the electric grid.

Course Learning Outcomes

- With respect to the current broad trends in energy utilization in buildings : 1. Assess quantitative trends and major forces behind the past and future evolution with respect to energy utilization in residential buildings, commercial sector, and major industries; 2. Analyze cooling and heating loads of residential buildings and commercial buildings as a function of HVAC technology and geographical location; 3. Evaluate historical trends and new technologies in reducing and increasing electric, heating, and cooling demands of residential and commercial buildings;
- With respect to dynamic energy utilization for buildings: 4. Quantify the impacts of broad implementation of energy storage such as batteries and/or thermal energy storage on the impact of electric grid requirements; 5. Quantify how dynamic demand response or load management with energy storage can impact energy requirements for buildings/communities; 6. Describe the role of LEED Certification in driving building energy efficiency;
- With respect to energy utilization for industrial processes: 7. Analyze two energy intensive manufacturing processes (chemical or materials) and write review of technologies that impact their energy needs, requirements, and costs over the next two decades; 8. Develop understanding of how changing energy and utility supplies can impact process efficiency and environmental impact on energy intensive manufacturing processes; 9. Articulate the impact of PURPA (Public Utility Regulatory Policies Act), and Energy Policy Acts of 1992, and 2005.
- With respect to advanced energy grids and distributed power: 10. Articulate advances in distributed power and advanced controls and their impact upon grid operation and utility markets in a smart grid framework for the U.S.; 11. Evaluate for one energy-intensive industrial process the energy, economic benefits for combined heat and power or combined cooling, heat, and power; 12. Identify the challenges and risks arises due to cyber-security in a smart grid and articulate awareness of the essential tools used to secure grid infrastructure.

ENGY599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

ENGY691. INTRODUCTION TO RESEARCH METHODS IN THE ENERGY SCIENCES. 3.0 Semester Hrs.

This course introduces graduate students enrolled in the Advanced Energy Systems Program to research opportunities, culture, and expectations in energy science and technology with a particular emphasis on systems and/or policy analysis. Students will work within directorates at NREL with an emphasis on systems modeling, analysis, and/or integration. This class will engage students in a semester-long research project in energy system analysis and prepare students for best practices with respect to research project and data management, literature reading, report writing, and presentation.

Course Learning Outcomes

- With respect to research skills and practices: 1. Learn how to perform a detailed literature review and summary in support of a research project; 2. Develop strong habits for documenting research progress and reporting to other researchers and management on regular basis; 3. Exhibit working knowledge of good practices in data management during research; 4. Demonstrate competency in presenting research in a professional, technical presentation;
- With respect to energy systems analysis: 5. Perform a publication-quality techno-economic or systems analysis to assess energy-relevant technology, innovation, or policy for informing decision-making; 6. Leverage existing models and develop new models to evaluate advanced energy technologies, systems, and services.

ENGY692. PROJECT FOCUSED RESEARCH IN ENERGY SCIENCE & TECHNOLOGY. 3.0 Semester Hrs.

(I) This course prepares graduate students enrolled in the Advanced Energy Systems Program in research practices, culture, and expectations in energy science and technology with a particular emphasis on science and engineering related to energy materials, processes, and/or systems. Students will work within directorates at NREL with an emphasis on science and/or technology. This class will engage students in a semester-long research project in energy science and/or technology. Students will also learn and practice journal publication and research poster best practices, research career path planning, and proposal funding strategies. 1 hour lecture; 6 hours lab; 3 semester hours.

Course Learning Outcomes

- With respect to journal article and poster preparation: 1. Develop strong skills in literature review and paper preparation; 2. Demonstrate skills with respect to preparing a publication outline and figure list; 3. Write a report that has the structure and quality of a journal publication; 4. Prepare a poster summarizing research motivation and results from semester project;
- With respect to career development and supporting skills: 5. Articulate career paths related to advanced energy systems and identifying skills for preparation 6. Prepare and critique proposal project summaries for energy-related science and technology research; 7. Demonstrate ability to identify funding opportunities and promote research;
- With respect to energy science, technology, and innovation research: 8. Perform a research study on an advance energy science and technology development in line with career and research interest and NREL programs; 9. Demonstrate working knowledge of best laboratory practices with respect to safety, notebook recording, and uncertainty. 10. Be able to motivate the topic of research

through techno-economic analysis 11. Be able to define a research hypothesis and develop a parametric test procedure to evaluate it

ENGY693. AES GRADUATE STUDENT SEMINAR. 0.5 Semester Hrs.
The Advanced Energy Systems Graduate Student Seminar is a series of presentations provided by graduate students to fellow graduate students, faculty, mentors, and guests. All Ph.D. students are expected to register for this course. The seminar course provides students, faculty, and mentors working in the AES Graduate Program an opportunity to hear updates on current research within the various cohorts and provides a chance for students to get constructive feedback on their presentation. In addition, the course will provide a venue for discussions on various topics related to methods for succeeding in research careers in academia, national labs, and industry, and topics of the day. The course format will be to have two graduate-student presentations with critical feedback, followed by a discussion session on various professional development topics.