ENERGY RESOURCES ENGINEERING

Courses offered by the Department of Energy Resources Engineering (ERE) are listed under the subject code ENERGY on the (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=ENERGY&filter-catalognumber-ENERGY=on) Stanford Bulletin's (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=ENERGY&filter-catalognumber-ENERGY=on) ExploreCourses web site (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=ENERGY&filter-catalognumber-ENERGY=on).

The Department of Energy Resources Engineering (ERE) awards the following degrees: Bachelor of Science, Master of Science, Engineer, and Doctor of Philosophy in Energy Resources Engineering. The department also awards the Master of Science, Engineer, and Doctor of Philosophy degrees in Petroleum Engineering. Contact the ERE student services office to determine the relevant program.

Energy Resources Engineering contributes to the engineering science needed to maintain and diversify the energy supply while finding the most rapid pathways toward greater energy sustainability. Energy Resources Engineering is concerned with the production, transformation, and impacts of energy resources including renewables and fossil fuels. Oil and natural gas are important components of the current energy system due to their widespread use, economic importance, and contributions to climate change. The flow of water, oil, and gas in the subsurface are important to quantify accurately for energy recovery, energy storage, environmental assessment, and carbon storage.

The program also has a strong interest in related energy topics such as renewable energy, global climate change, carbon capture and sequestration, energy storage and energy systems. The Energy Resources Engineering curriculum provides a sound background in basic sciences and their application to practical problems to address the complex and changing nature of the field. Course work includes the fundamentals of physics, chemistry, geology, computational physics, numerical analysis, and engineering science. Applied courses cover most aspects of energy resources engineering and some related fields such as geostatistics. The curriculum includes the fundamental aspects of energy transfer and fluid flow in subsurface geologic formations, as well as the storage, transmission and utilization of energy at the surface. These principles apply to the optimization of energy recovery from hydrocarbon and geothermal reservoirs, subsurface sequestration of carbon dioxide, energy storage, and the remediation of groundwater systems.

Faculty, graduate students, and postdoctoral scholars conduct research in areas including: energy system modeling and optimization; energy storage; data assimilation and uncertainty quantification; numerical reservoir simulation; carbon sequestration; enhanced oil recovery; geostatistical reservoir characterization; geothermal engineering; production optimization; power production from wind and wave energy; and well test analysis. Undergraduates are encouraged to participate in research projects.

The department is housed in the Green Earth Sciences Building and operates laboratories for research in batteries and energy storage, enhanced oil recovery processes, geological carbon storage operations, and geothermal engineering. Students have access to a variety of computer platforms and software for research and course work.

Mission of the Undergraduate Program in Energy Resources Engineering

The mission of the Energy Resources Engineering major is to provide students with the engineering skills and foundational knowledge needed to flourish as technical leaders within the energy industry. Such skills and knowledge include resource assessment, choices among energy alternatives, and carbon management, as well as the basic scientific background and technical skills common to engineers. The curriculum is designed to prepare students for immediate participation in many aspects of the energy industry and graduate school.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to:

1. apply skills developed in fundamental courses to real-world engineering problems.
2. research, analyze, and synthesize solutions to an original and contemporary energy problem.
3. work independently and as part of a team to develop and improve engineering solutions.
4. apply written, visual, and oral presentation skills to communicate engineering and scientific knowledge.

Graduate Programs in Energy Resources Engineering

The Energy Resources Engineering department offers two distinct degree programs at both the M.S and Ph.D. levels. One program leads to the degrees of M.S. or Ph.D. in Energy Resources Engineering, and the other leads to the degrees of M.S. or Ph.D. in Petroleum Engineering. The Engineer degree, which is offered in either Energy Resources Engineering or Petroleum Engineering, is an extended form of the M.S. degree with additional course work and research.

Learning Outcomes (Graduate)

The objective is to prepare students to be technical leaders in the energy industry, academia and research organizations through completion of independent research as well as fundamental courses in the major field and in related sciences. Students are expected to:

1. apply skills developed in fundamental courses to engineering problems.
2. research, analyze, and synthesize solutions to an original and contemporary energy problem.
3. work independently and as part of a team to develop and improve engineering solutions.
4. apply written, visual, and oral presentation skills to communicate scientific knowledge.
5. M.S. students are expected to develop in-depth technical understanding of energy problems at an advanced level.
6. Ph.D. students are expected to complete a scientific investigation that is significant, challenging and original.

Bachelor of Science in Energy Resources Engineering

The four-year program leading to the B.S. degree provides a foundation for careers in many facets of the energy industry. The curriculum includes basic science and engineering courses that provide sufficient depth for a wide spectrum of careers in the energy, engineering, and environmental fields.

One of the goals of the program is to provide experience integrating the skills developed in individual courses to address a significant design problem. In ENERGY 199 Senior Project and Seminar in Energy Resources, taken in the senior year, student teams identify and propose technical solutions for an energy-resource related problem of current interest.

Program

The requirements for the B.S. degree in Energy Resources Engineering are similar, but not identical, to those described in the "School of Engineering" section of this bulletin. Students must satisfy the University Thinking Matters, Ways of Thinking/Ways of Doing (Ways), writing and rhetoric, and language requirements. The normal Energy Resources Engineering undergraduate program automatically satisfies the University Ways requirement in the Disciplinary Breadth areas of Natural Sciences, Engineering and Applied Sciences, and Mathematics.

Courses taken to fulfill the requirements for the major (energy resources core and depth; mathematics; engineering fundamentals; science; and technology in society) must be taken for a letter grade if the option is offered.

The Energy Resources Engineering undergraduate curriculum is designed to prepare students for participation in the energy industry or for graduate studies, while providing requisite skills to evolve as the energy landscape shifts over the next half century. The program provides a background in mathematics, basic sciences, and engineering fundamentals such as multiphase fluid flow in the subsurface. In addition, the curriculum is structured with flexibility that allows students to explore energy topics of particular individual interest and to study abroad.

In brief, the unit and subject requirements are:

	Units
Energy Resources Core	15-16
Energy Resources Depth	18
Mathematics	25
Engineering Fundamentals and Depth	20-24
Science	29-32
Technology in Society	3-5
University Requirements: Ways, Writing, Language	60-70
Total Units	170-190

The following courses constitute the normal program leading to a B.S. in Energy Resources Engineering. The program may be modified to meet a particular student's needs and interests with the adviser's prior approval.

Required Core in Energy Resources Engineering

		Units
The following courses constitute the core program in Energy Resources Engineering		
ENERGY 101	Energy and the Environment	3
ENERGY 104	Sustainable Energy for 9 Billion	3
ENERGY 120	Fundamentals of Petroleum Engineering	3
ENERGY 160	Uncertainty Quantification in Data-Centric Simulations	3
ENERGY 199	Senior Project and Seminar in Energy Resources (WIM)	3-4
Mathematics		**10**
MATH 19	Calculus	
MATH 20	Calculus	
MATH 21	Calculus	
And the following (CME series recommended):		
CME 100	Vector Calculus for Engineers	5
or MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
CME 102	Ordinary Differential Equations for Engineers	5
or MATH 53	Ordinary Differential Equations with Linear Algebra	
CME 104	Linear Algebra and Partial Differential Equations for Engineers	5
or MATH 52	Integral Calculus of Several Variables	
Science		
CHEM 31A	Chemical Principles I	5
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 31B	Chemical Principles II	5
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
PHYSICS 41	Mechanics	4
PHYSICS 43	Electricity and Magnetism	4
PHYSICS 45	Light and Heat	4
PHYSICS 46	Light and Heat Laboratory	1
GEOLSCI 1	Introduction to Geology	5
Engineering Fundamentals		
CS 106A	Programming Methodology	3-5
or CS 106X	Programming Abstractions	
CS 106B	Programming Abstractions	3-5
or CS 106X	Programming Abstractions	
ENERGY 110	Engineering Economics	3
ENGR 14	Intro to Solid Mechanics	3
ME 30	Engineering Thermodynamics (Previously ENGR 30)	3
ME 70	Introductory Fluids Engineering	3
Technology in Society, 1 course		

Earth and Energy Depth

Complete at least 5 courses from either the Renewable and Clean Energy or Petroleum Engineering emphasis lists below. Complete at least one course from the other emphasis. Units must total to at least 18 units.

		Units
Renewable and Clean Energy		
ENERGY 102	Fundamentals of Renewable Power	3
ENERGY 153	Carbon Capture and Sequestration	3-4
ENERGY 191	Optimization of Energy Systems	3-4
ENERGY 262	Physics of Wind Energy	3
ENERGY 293	Energy storage and conversion: Solar Cells, Fuel Cells, Batteries and Supercapacitors	3
ENERGY 293B	Fundamentals of Energy Processes	3
CEE 70	Environmental Science and Technology	3
CEE 176A	Energy Efficient Buildings	3
CEE 176B	100% Clean, Renewable Energy and Storage for Everything	3-4
Petroleum Engineering		
ENERGY 112	Exploring Geosciences with MATLAB	1-3
ENERGY 118	Safety and Environmental Aspects of Energy Production	3
ENERGY 121	Fundamentals of Multiphase Flow	3
ENERGY 130	Well Log Analysis I	3

ENERGY 141	Seismic Reservoir Characterization	3-4
ENERGY 153	Carbon Capture and Sequestration	3-4
ENERGY 175	Well Test Analysis	3
ENERGY 180	Oil and Gas Production Engineering	3
ENERGY 191	Optimization of Energy Systems	3-4
GEOLSCI 106	Sediments: The Book of Earth's History	3
GEOPHYS 130	Introductory Seismology	3
GEOPHYS 182	Reflection Seismology	3

Honors Program

The program in Energy Resources Engineering leading to the Bachelor of Science with Honors provides an opportunity for independent study and research on a topic of special interest and culminates in a written report and oral presentation.

The honors program is open to students with a grade point average (GPA) of at least 3.5 in all courses required for the ERE major and minimum of 3.0 in all University course work. Qualified students intending to pursue honors must submit an Honors Program Application to the undergraduate program director no later than the eighth week of their ninth quarter, but students are encouraged to apply to the program during Winter Quarter of their junior year. The application includes a short form, an unofficial transcript, and a 2-3 page research proposal prepared by the student and endorsed by a faculty member who serves as the research adviser.

Upon approval, students enroll in the honors program via Axess. Students must enroll in a total of 9 units of ENERGY 193 Undergraduate Research Problems; these units may be spread out over the course of the senior year, and may include previous enrollment units for the same research project. Research undertaken for the honors program cannot be used as a substitute for regularly required courses. A formal written report must be submitted to the student's research adviser no later than the fourth week of the student's final quarter, and the report must be read, approved, and signed by the student's faculty adviser and a second member of the faculty. Each honors candidate must make an oral presentation of his or her research results.

Minor in Energy Resources Engineering

The minor in Energy Resources Engineering requires the following three courses plus three additional electives. Courses must be planned in consultation with an ERE adviser. Appropriate substitutions are allowed with the consent of the adviser.

Required courses

		Units
ENERGY 101	Energy and the Environment	3
ENERGY 120	Fundamentals of Petroleum Engineering	3
ENERGY 160	Uncertainty Quantification in Data-Centric Simulations	3

Elective courses

		Units
Select at least three of the following:		
ENERGY 102	Fundamentals of Renewable Power	
ENERGY 104	Sustainable Energy for 9 Billion	
ENERGY 112	Exploring Geosciences with MATLAB	
ENERGY 121	Fundamentals of Multiphase Flow	
ENERGY 130	Well Log Analysis I	
ENERGY 141	Seismic Reservoir Characterization	
ENERGY 153	Carbon Capture and Sequestration	
ENERGY 175	Well Test Analysis	
ENERGY 180	Oil and Gas Production Engineering	
ENERGY 269	Geothermal Reservoir Engineering	
GEOLSCI 106	Sediments: The Book of Earth's History	
GEOPHYS 182	Reflection Seismology	

The department offers a Master of Science in Energy Resources Engineering (p. 3), a coterminal Master of Science in Energy Resources Engineering (p. 4), and a Master of Science in Peetroleum Engineering (p. 5).

Master of Science in Energy Resources Engineering

The objective of the M.S. degree in Energy Resources Engineering is to prepare the student either for a professional career or for doctoral studies. Students in the M.S. degree program must fulfill the following:

1. Complete a 45-unit program of study. The degree has two options:
   a. a course work degree, requiring 45 units of course work
   b. a research degree, with a minimum of 39 units of course work, and the remainder consisting of no more than 6 research units.
2. Complete 3 units of ENERGY 351 ERE Master's Graduate Seminar. These units do not count toward the 45 units of course work required for the M.S. degree.
3. Course work units must be divided among two or more scientific and/or engineering disciplines and can include the core courses required for the Ph.D. degree.
4. All courses must be taken for a letter grade.
5. The program of study must be approved by the academic advisor and the department graduate program committee.
6. Students taking the research-option degree are required to complete an M.S. thesis, approved by the student's thesis committee.

Recommended Courses and Sequences

The following list is recommended for most students. With the prior consent of the student's advisor, courses listed under technical electives may be substituted based on interest or background.

Core Sequence (12 units)

		Units
ENERGY 253	Carbon Capture and Sequestration	3-4
ENERGY 293	Energy storage and conversion: Solar Cells, Fuel Cells, Batteries and Supercapacitors	3
ENERGY 293B	Fundamentals of Energy Processes	3
ENERGY 297	Fluid Mechanics and Heat Transfer	3

Mathematics and Analysis Fundamentals (12 units)

		Units
CME 200	Linear Algebra with Application to Engineering Computations	3
And select one of the following (3 units):		
CME 204	Partial Differential Equations in Engineering	3
CME 206	Introduction to Numerical Methods for Engineering	3
ENERGY 281	Applied Mathematics in Reservoir Engineering	3
And select two of the following (6 units):		
ENERGY 240	Data science for geoscience	3
ENERGY 260	Uncertainty Quantification in Data-Centric Simulations	3
ENERGY 281	Applied Mathematics in Reservoir Engineering	3
ENERGY 291	Optimization of Energy Systems	3-4

CME 204	Partial Differential Equations in Engineering	3
CME 206	Introduction to Numerical Methods for Engineering	3

Technical Elective Sequence (15 units)

		Units
Select three courses from one of the following sequences and additional technical courses to obtain 15 total elective units:		15
Geothermal:		
Select three of the following:		
ENERGY 223	Reservoir Simulation	
ENERGY 269	Geothermal Reservoir Engineering	
ME 131	Heat Transfer	
ME 370A	Energy Systems I: Thermodynamics	
Low Carbon Energy:		
Select three of the following:		
ENERGY 104	Sustainable Energy for 9 Billion	
ENERGY 223	Reservoir Simulation	
ENERGY 251	Thermodynamics of Equilibria	
ENERGY 269	Geothermal Reservoir Engineering	
ENERGY 291	Optimization of Energy Systems	
ME 370A	Energy Systems I: Thermodynamics	
ME 370B	Energy Systems II: Modeling and Advanced Concepts	
Modeling Natural Resources:		
Select three of the following:		
ENERGY 240	Data science for geoscience	
ENERGY 241	Seismic Reservoir Characterization	
GEOPHYS 262	Rock Physics	
Oil and Gas:		
Select three of the following:		
ENERGY 104	Sustainable Energy for 9 Billion	
ENERGY 175	Well Test Analysis	
ENERGY 221	Fundamentals of Multiphase Flow	
ENERGY 222	Advanced Reservoir Engineering	
ENERGY 223	Reservoir Simulation	
ENERGY 240	Data science for geoscience	
ENERGY 251	Thermodynamics of Equilibria	
Total Units		15

Research Sequence (6 units)

		Units
ENERGY 361	Master's Degree Research in Energy Resources Engineering [1]	1-6
Total Units		1-6

1 Students choosing the self-funded course-work-only option for the M.S. degree may substitute an additional elective sequence in place of the research.

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Coterminal M.S. Program in Energy Resources Engineering

The coterminal B.S./M.S. program offers an opportunity for Stanford University students to pursue a graduate experience while completing the B.S. degree in any relevant major. Energy Resources Engineering graduate students generally come from backgrounds such as chemical, civil, or mechanical engineering; geology or other earth sciences; or physics or chemistry.

The two types of M.S. degrees, the course work only degree and the research degree, as well as the courses required to meet degree requirements, are described above in the M.S. section. Both degrees require 45 units and may take from one to two years to complete depending on circumstances unique to each student.

Requirements to enter the program are: three letters of recommendation from faculty members or job supervisors, a statement of purpose, scores from the GRE general test, and a copy of Stanford University transcripts. While the department does not require any specific GPA or GRE score, potential applicants are expected to compete favorably with graduate student applicants.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/cotermdegrees/)" section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate advisor be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

A Petroleum Engineering or Energy Resources Engineering master's degree can be used as a terminal degree for obtaining a professional job in the engineering or energy industries, or in any related industry where application of physical principles or computer simulation skills are required. It can also be a stepping stone to a Ph.D. degree that usually leads to a professional research job or an academic position.

Students should apply to the program any time after they have completed 120 undergraduate units. Contact the Department of Energy Resources Engineering to obtain additional information. Students should have a background at least through MATH 53 (http://exploredegrees.stanford.edu/schoolofearthsciences/energyresourcesengineering/js/fckeditor/editor/fckeditor.html?InstanceName=attr_text&Toolbar=PageWizard) Ordinary Differential Equations with Linear Algebra and CS 106AB (http://exploredegrees.stanford.edu/schoolofearthsciences/energyresourcesengineering/js/fckeditor/editor/fckeditor.html?InstanceName=attr_text&Toolbar=PageWizard) Programming Methodology before beginning graduate work in this program.

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Master of Science in Petroleum Engineering

The objective is to prepare the student for professional work in the energy industry, or for doctoral studies, through completion of fundamental courses in the major field and in related sciences as well as independent research.

Students entering the graduate program are expected to have an undergraduate-level engineering or physical science background. Competence in computer programming in a high-level language (CS 106X Programming Abstractions or the equivalent) and knowledge of engineering and geological fundamentals (ENERGY 120 Fundamentals of Petroleum Engineering, ENERGY 130 Well Log Analysis I, and GEOLSCI 106 Sediments: The Book of Earth's History) are prerequisites for taking most graduate courses.

The following are minimum requirements for a student in the Department of Energy Resources Engineering to remain in good academic standing regarding course work:

1. No more than one incomplete grade at any time
2. A cumulative grade point average (GPA) of 3.0
3. A grade point average (GPA) of 2.7 each quarter
4. A minimum of 15 units completed within each two quarter period (excluding Summer Quarter).

Unless otherwise stated by the instructor, incomplete grades in courses within the department are changed to 'NP' (not passed) at the end of the quarter after the one in which the course was given. This one quarter limit is a different constraint from the maximum one-year limit allowed by the University.

Academic performance is reviewed each quarter by a faculty committee. At the beginning of the next quarter, any student not in good academic standing receives a letter from the committee or department chair stating criteria that must be met for the student to return to good academic standing. If the situation is not corrected by the end of the quarter, possible consequences include termination of financial support, termination of departmental privileges, and termination from the University.

Students funded by research grants or fellowships from the department are expected to spend at least half of their time (a minimum of 20 hours per week) on research. Continued funding is contingent upon satisfactory research effort and progress as determined by the student's advisor. After Autumn Quarter of the first year, students receive a letter from the department chair concerning their research performance. If problems are identified and they persist through the second quarter, a warning letter is sent. Problems persisting into a third quarter may lead to loss of departmental support including tuition and stipend. Similar procedures are applied in subsequent years.

A balanced master's degree program including engineering course work and research requires a minimum of one maximum-tuition academic year beyond the baccalaureate to meet the University residence requirements. Most full-time students spend at least one additional summer to complete the research requirement. An alternative master's degree program based only on course work is available, also requiring at least one full tuition academic year to meet University residence requirements.

M.S. students who anticipate continuing in the Ph.D. program should follow the research option. M.S. students receiving financial aid normally require two academic years to complete the degree. Such students must take the research option.

The candidate must fulfill the following requirements:

1. Register as a graduate student for at least 45 units.
2. Submit a program proposal for the Master's degree approved by the advisor during the first quarter of enrollment.
3. Complete 45 units with a grade point average (GPA) of at least 3.0. This requirement is satisfied by taking the core sequence, selecting one of the seven elective sequences, an appropriate number of additional courses from the list of technical electives, and completing 6 units of master's level research. Students electing the course work only M.S. degree are strongly encouraged to select an additional elective sequence in place of the research requirement. Students interested in continuing for a Ph.D. are expected to choose the research option and enroll in 6 units of ENERGY 361 Master's Degree Research in Energy Resources Engineering. All courses must be taken for a letter grade.
4. Complete 3 units of ENERGY 351 ERE Master's Graduate Seminar. These units do not count toward the 45 units of course work required for the M.S. degree.
5. Students entering without an undergraduate degree in Petroleum Engineering must make up deficiencies in previous training. Not more than 10 units of such work may be counted as part of the minimum total of 45 units toward the M.S. degree.

Research subjects include certain groundwater hydrology and environmental problems, energy industry management, flow of non-Newtonian fluids, geothermal energy, natural gas engineering, oil and gas recovery, pipeline transportation, production optimization, reservoir characterization and modeling, carbon sequestration, reservoir engineering, reservoir simulation, and transient well test analysis.

Recommended Courses and Sequences

The following list is recommended for most students. With the prior special consent of the student's advisor, courses listed under technical electives may be substituted based on interest or background.

Core Sequence (12 units)

		Units
ENERGY 221	Fundamentals of Multiphase Flow	3
ENERGY 222	Advanced Reservoir Engineering	3
ENERGY 251	Thermodynamics of Equilibria	3
ENERGY 297	Fluid Mechanics and Heat Transfer	3

Mathematics and Analysis Fundamentals (12 units)

		Units
CME 200	Linear Algebra with Application to Engineering Computations	3
And select one of the following (3 units):		
CME 204	Partial Differential Equations in Engineering	3
CME 206	Introduction to Numerical Methods for Engineering	3
ENERGY 281	Applied Mathematics in Reservoir Engineering	3
And select two of the following (6 units):		
ENERGY 240	Data science for geoscience	3
ENERGY 260	Uncertainty Quantification in Data-Centric Simulations	3
ENERGY 281	Applied Mathematics in Reservoir Engineering	3
ENERGY 291	Optimization of Energy Systems	3-4
CME 204	Partial Differential Equations in Engineering	3
CME 206	Introduction to Numerical Methods for Engineering	3

Technical Elective Sequence (15 units)

		Units
Select three courses from one of the following sequences and additional technical courses to obtain 15 total elective units:		15
Environmental:		
ENERGY 227	Enhanced Oil Recovery	
ESS 221	Contaminant Hydrogeology and Reactive Transport	
CEE 270	Movement and Fate of Organic Contaminants in Waters	
Enhanced Recovery:		
Select three of the following:		
ESS 220	Physical Hydrogeology	
ENERGY 225	Theory of Gas Injection Processes	
ENERGY 226	Thermal Recovery Methods	
ENERGY 227	Enhanced Oil Recovery	
Geostatistics and Reservoir Modeling:		
ENERGY 240	Data science for geoscience	
ENERGY 241	Seismic Reservoir Characterization	
GEOPHYS 182	Reflection Seismology	
or GEOPHYS 262	Rock Physics	
Geothermal:		
ENERGY 269	Geothermal Reservoir Engineering	
CHEMENG 120B	Energy and Mass Transport	
ME 131	Heat Transfer	
Reservoir Performance:		
Select three of the following:		
ENERGY 130	Well Log Analysis I	
ENERGY 175	Well Test Analysis	
ENERGY 223	Reservoir Simulation	
ENERGY 280	Oil and Gas Production Engineering	
GEOPHYS 202	Reservoir Geomechanics	
Simulation and Optimization:		
ENERGY 223	Reservoir Simulation	
ENERGY 224	Advanced Reservoir Simulation	
ENERGY 289	Multiscale Methods for Transport in Porous Media	
Renewable Energy:		
Select three of the following:		
ENERGY 269	Geothermal Reservoir Engineering	
or ENERGY 262	Physics of Wind Energy	
ENERGY 293	Energy storage and conversion: Solar Cells, Fuel Cells, Batteries and Supercapacitors	
ENERGY 293B	Fundamentals of Energy Processes	
ENERGY 295	Electrochemical Energy Storage Systems: Modeling and Estimation	

Research Sequence (6 units)

		Units
ENERGY 361	Master's Degree Research in Energy Resources Engineering [1]	1-6
Total Units		1-6

[1] Students choosing the self-funded course-work-only option for the M.S. degree may substitute an additional elective sequence in place of the research.

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Doctor of Philosophy in Petroleum Engineering or Energy Resources Engineering

The Ph.D. degree is conferred upon demonstration of high achievement in independent research and by presentation of the research results in a written dissertation and oral defense.

The following are minimum requirements for a student in the Department of Energy Resources Engineering to remain in good academic standing regarding course work:

1. No more than one incomplete grade at any time
2. A cumulative grade point average (GPA) of 3.25
3. A grade point average (GPA) of 2.7 each quarter
4. A minimum of 15 units completed within each two quarter period (excluding Summer Quarter).

Unless otherwise stated by the instructor, incomplete grades in courses within the department are changed to 'NP' (not passed) at the end of the quarter after the one in which the course was given. This one quarter limit is a different constraint from the maximum one-year limit allowed by the University.

Academic performance is reviewed each quarter by a faculty committee. At the beginning of the next quarter, any student not in good academic standing receives a letter from the committee or department chair stating criteria that must be met for the student to return to good academic standing. If the situation is not corrected by the end of the quarter, possible consequences include termination of financial support, termination of departmental privileges, and dismissal from the University.

Students funded by research grants or fellowships from the department are expected to spend at least half of their time (a minimum of 20 hours per week) on research. Continued funding is contingent upon satisfactory research effort and progress as determined by the student's advisor. After Autumn Quarter of the first year, students receive a letter from the department chair concerning their research performance. If problems are identified and they persist through the second quarter, a warning letter is sent. Problems persisting into a third quarter may lead to loss of departmental support including tuition and stipend. Similar procedures are applied in subsequent years.

The Ph.D. degree is awarded primarily on the basis of completion of significant, original research. Extensive course work and a minimum of 90 units of graduate work beyond the master's degree are required. Doctoral candidates planning theoretical work are encouraged to gain experimental research experience in the M.S. program. Ph.D. students receiving financial assistance are limited to 10 units per quarter and often require more than three years beyond the M.S. degree to complete the Ph.D.

In addition to University and the Department of Energy Resources Engineering basic requirements for the doctorate, the Petroleum Engineering Ph.D. and Energy Resources Engineering Ph.D. degrees have the following requirements:

1. Complete 135 units of total graduate work (90 units beyond the master's degree). The 90 units are composed of a minimum of 36 units of research and a minimum of 36 units of course work. At least half of the classes must be at a 200 level or higher and all must be taken for a letter grade. Students with an M.S. degree or other specialized training from outside ERE are generally expected to include ENERGY 221 Fundamentals of Multiphase Flow, ENERGY 297 Fluid Mechanics and Heat Transfer and ENERGY 240 Data science for geoscience, or their equivalents. The number and distribution

of courses to be taken is determined with input from the research advisors and department graduate program committee.

2. To achieve candidacy (usually during or at the end of the first year of enrollment), the student must complete 24 units of letter-graded course work beyond the M.S. degree, pass a written exam, develop a written Ph.D. research proposal, and choose a dissertation committee.
3. The research advisor(s) and two other faculty members comprise the dissertation reading committee. Upon completion of the dissertation, the student must pass a University oral examination in defense of the dissertation.
4. Act as a teaching assistant at least once, and enroll in ENERGY 359 Teaching Experience in Energy Resources Engineering.
5. Complete 4 units of ENERGY 352 ERE PhD Graduate Seminar. These units do not count toward the 36 units of course work required for the Ph.D. degree.

36 units of course work is a minimum; in some cases the research advisor may specify additional requirements to strengthen the student's expertise in particular areas. The 36 units of course work does not include required teaching experience (ENERGY 359 Teaching Experience in Energy Resources Engineering) nor required research seminars.

The dissertation must be submitted in its final form within five calendar years from the date of admission to candidacy. Candidates who fail to meet this deadline must submit an Application for Extension of Candidacy for approval by the department chair if they wish to continue in the program.

Ph.D. students entering the department are required to hold an M.S. degree in a relevant science or engineering discipline. Students wishing to follow the Ph.D. program in Petroleum Engineering must hold an M.S. degree (or equivalent) in Petroleum Engineering. Students following the Ph.D. program in Energy Resources Engineering must hold an M.S. degree (or equivalent), although it need not be in Energy Resources Engineering.

After the second quarter at Stanford, a faculty committee evaluates the student's progress. If a student is found to be deficient in course work and/or research, a written warning is issued. After the third quarter, the faculty committee decides whether or not funding should be continued for the student. Students denied funding after the third quarter are advised against proceeding with the Ph.D. proposal, though the student may choose to proceed under personal funding.

Ph.D. Degree Qualification

The procedure for Ph.D. qualification is identical for individuals who entered the department as an M.S. or as a Ph.D. student. For students completing an M.S. in the department, the student formally applies to the Ph.D. program in the second year of the M.S. degree program. The student is considered for admission to the Ph.D. program along with external applicants. The admission decision is based primarily upon research progress and course work.

There are two steps to the qualification procedure. Students first take a written exam that is offered just before the beginning of Autumn Quarter. The exam focuses upon synthesis of knowledge acquired from the core courses in ERE, or PE. Typically, students are expected to have expertise in the materials of the following classes:

ERE: ENERGY 240, 253, 293, 293B, 297 (or 221), CME 200, 204 (or ENERGY 281)

PE: ENERGY 175, 221, 222, 223, 240, 251, 260, CME 200, 204 (or ENERGY 281)

The exams are different for ERE and PE Ph.D. students, but share a goal of having students exhibit capability to solve engineering problems in the subject. Students take the exam consistent with their Ph.D. degree objective (i.e., ERE or PE).

Students continuing within the department take the written exam at the beginning of their first quarter as Ph.D. students. Students who completed their M.S. outside of the department take the written exam at the beginning of their fourth quarter as Ph.D. students. A student who does not pass the exam may be allowed to take the exam a second time; however this is a decision of the examining faculty committee. Any student who does not pass the written exam is considered to have failed the qualifying exam. Any student who is deemed to have not made sufficient research progress may not be allowed to take the written exam and research progress is taken into account for pass, fail, and retake decisions.

The second step of the Ph.D. qualifying procedure includes a written Ph.D. proposal and oral defense. Each student must select a committee of three faculty members, including the advisor(s), who read the proposal and attend the oral defense. The other committee members should be chosen in consultation with the advisor(s). One of the committee members can be a senior research scientist, or an external researcher, where appropriate. In the case of a coadvising situation, the committee may include a total of four members (three is also acceptable in this case).

The body of the written proposal, including references, should be 25-35 pages in length (note the 35-page maximum). The written proposal can additionally include, as appendices, papers that have been published or submitted, but the student should not expect the committee to read the material in the appendices. Templates (11-point font, normal margins) for the proposal should be used and are available on the department's website (https://pangea.stanford.edu/ere/current-student-resources/). The proposal, with approximate lengths for the various sections, should include:

- Introduction and literature review, including key unanswered research questions (4-8 pages)
- Problem statement and research progress to date, including formulations, data and methods used (or to be applied), initial results and discussion, etc. (15-25 pages)
- Proposed work, intellectual/practical merit, timeline (3-5 pages)
- References

The proposal must be provided to the committee, both as hard copy and via email, a minimum of two weeks prior to the oral defense. This two-week lead time is a firm requirement. The oral proposal should be scheduled for two hours. This will include a formal talk, of length 35-40 minutes, followed by questions from each committee member. Questions may be on the proposed research as well as the general field of study. The student can pass, pass with qualifications requiring more classes or teaching assistantships, or fail.

Students who completed their M.S. in the department must prepare and defend their proposal in their third quarter, not counting summer, as a Ph.D. student (this will typically be spring quarter). Students who completed their M.S. outside of the department must complete the proposal in their fourth quarter of study, not counting summer (which will typically be fall quarter of their second year). In either case the advisor may request a one-quarter delay for extenuating circumstances such as a major change in research focus between M.S. and Ph.D. programs, serious health issues, etc. Note that this request must originate from the advisor, not the student.

Students who have passed the qualification procedure and later wish to change their degree objective from PE to ERE, or vice versa, may petition the graduate standing committee. A switch of degree objective is not automatically granted. Petitions are made in writing and must include a brief explanation of the request for a change in degree objective and a plan to make up subject matter deficiencies. At minimum, students who petition are expected to complete ultimately all courses listed as contributing subject matter to the written exam in the area of their degree objective with a minimum grade of 'B'. The graduate standing committee decides whether petitions have merit and if additional steps are needed to address deficiencies. Such switches in degree objective are considered provisional until all conditions have been met.

Course Work

The 36 units of course work may include graduate courses in Energy Resources Engineering (numbered 200 and above) and courses chosen from the following list. Other courses may be substituted with prior approval of the advisor. In general, non-technical courses are not approved.

Students who enter directly into the Ph.D. program after receiving an M.S. degree from another university are expected to show expertise in the core courses required for Stanford's M.S. degree in Energy Resources Engineering, either by including those courses in their Ph.D. degree or by showing that they have taken equivalent courses during their M.S. degree.

For a Ph.D. in Energy Resources Engineering, 12 of the 36 required course units must be completed from the following list of courses. If the student has not taken ENERGY 293 Energy storage and conversion: Solar Cells, Fuel Cells, Batteries and Supercapacitors and ENERGY 293B Fundamentals of Energy Processes or their equivalent during the M.S., then these courses must be taken during the Ph.D. (they satisfy 6 of the required 12 units).

		Units
Required to take 12 units from the following list:		
ENERGY 104	Sustainable Energy for 9 Billion	3
ENERGY 253	Carbon Capture and Sequestration	3-4
ENERGY 269	Geothermal Reservoir Engineering	3
ENERGY 291	Optimization of Energy Systems	3-4
ENERGY 293	Energy storage and conversion: Solar Cells, Fuel Cells, Batteries and Supercapacitors	3
ENERGY 293B	Fundamentals of Energy Processes	3
ENERGY 301	The Energy Seminar	1
CEE 176A	Energy Efficient Buildings	3
CEE 176B	100% Clean, Renewable Energy and Storage for Everything	3-4
CME 206	Introduction to Numerical Methods for Engineering	3
CME 302	Numerical Linear Algebra	3
CME 306	Numerical Solution of Partial Differential Equations	3
ESS 221/CEE 260C	Contaminant Hydrogeology and Reactive Transport	3
CHEMENG 340	Molecular Thermodynamics	3
ECON 250	Environmental Economics	3-5
ECON 251	Natural Resource and Energy Economics	2-5
GEOLSCI 253	Petroleum Geology and Exploration	3
GEOPHYS 182	Reflection Seismology	3
GEOPHYS 202	Reservoir Geomechanics	3
GEOPHYS 262	Rock Physics	3
ME 131	Heat Transfer	4
ME 335A	Finite Element Analysis	3
ME 335B	Finite Element Analysis	3
ME 335C	Finite Element Analysis	3
ME 370A	Energy Systems I: Thermodynamics	3
ME 370B	Energy Systems II: Modeling and Advanced Concepts	4
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	3-4
MATSCI 316	Nanoscale Science, Engineering, and Technology	3

Ph.D. Minor in Another Department

- The student must propose the possibility of pursuing a Ph.D. minor, clearly and explicitly, in the written Ph.D. proposal. This will then be discussed, and decided upon by the committee, during the oral portion of the Ph.D. proposal defense.

- Students can "double-count" a maximum of four courses toward both their ERE course requirements (36 units, typically 12 courses) and their minor requirements (e.g., 20 units in CS). This means that eight of the 12 courses required by ERE cannot also be applied for the minor. The course requirements for the ERE/PE Ph.D. degree must be approved in advance by the advisor as part of the Application for Candidacy. Any substitutions of courses to meet minor requirements cannot be made without the advisor's signed approval.

- We reiterate that students are required to review their course selections with their advisor at the start of every quarter.

Ph.D. Minor in Petroleum Engineering or Energy Resources Engineering

To be recommended for a Ph.D. degree with Petroleum Engineering or Energy Resources Engineering as a minor subject, a student must take 20 units of graduate-level lecture courses in the department. These courses must include ENERGY 221 Fundamentals of Multiphase Flow and ENERGY 222 Advanced Reservoir Engineering for the Petroleum Engineering minor, or ENERGY 293 Energy storage and conversion: Solar Cells, Fuel Cells, Batteries and Supercapacitors and ENERGY 293B Fundamentals of Energy Processes for the Energy Resources Engineering minor. The remaining courses should be selected from:

		Units
ENERGY 175	Well Test Analysis	3
ENERGY 223	Reservoir Simulation	3-4
ENERGY 224	Advanced Reservoir Simulation	3
ENERGY 225	Theory of Gas Injection Processes	3
ENERGY 227	Enhanced Oil Recovery	3
ENERGY 240	Data science for geoscience	3
ENERGY 241	Seismic Reservoir Characterization	3-4
ENERGY 251	Thermodynamics of Equilibria	3
ENERGY 253	Carbon Capture and Sequestration	3-4
ENERGY 269	Geothermal Reservoir Engineering	3
ENERGY 280	Oil and Gas Production Engineering	3
ENERGY 281	Applied Mathematics in Reservoir Engineering	3
ENERGY 291	Optimization of Energy Systems	3-4

COVID-19 Policies

On July 30, the Academic Senate adopted grading policies effective for all undergraduate and graduate programs, excepting the professional Graduate School of Business, School of Law, and the School of Medicine M.D. Program. For a complete list of those and other academic policies relating to the pandemic, see the "COVID-19 and Academic

Continuity (http://exploredegrees.stanford.edu/covid-19-policy-changes/#tempdepttemplatetabtext)" section of this bulletin.

The Senate decided that all undergraduate and graduate courses offered for a letter grade must also offer students the option of taking the course for a “credit” or “no credit” grade and recommended that deans, departments, and programs consider adopting local policies to count courses taken for a “credit” or “satisfactory” grade toward the fulfillment of degree-program requirements and/or alter program requirements as appropriate.

Undergraduate Degree Requirements

Grading

Under normal circumstances, all courses credited to the degree have been required to be taken for a letter grade. However, due to the special circumstances arising from the COVID-19 pandemic, this requirement is being relaxed for the 2020-21 academic year. Courses can be credited towards the degree requirements either if they have been taken for a letter grade or with a grade of 'CR' (credit) or 'S' (satisfactory).

Graduate Degree Requirements

Grading

Under normal circumstances, all courses credited to the degree have been required to be taken for a letter grade. However, due to the special circumstances arising from the COVID-19 pandemic, this requirement is being relaxed for the 2020-21 academic year. Courses can be credited towards the degree requirements either if they have been taken for a letter grade or with a grade of 'CR' (credit) or 'S' (satisfactory).

For a statement of University policy on graduate advising, see the "Graduate Advising (http://exploredegrees.stanford.edu/graduatedegrees/#advisingandcredentialstext)" section of this bulletin.

Master's Student Advising

The Department of Energy Resources Engineering is committed to providing academic advising in support of our M.S. students’ education and professional development. When most effective, this advising relationship entails collaborative engagement by both the advisor and the advisee. As a best practice, advising expectations should be discussed and reviewed to ensure mutual understanding. Both the advisor and the advisee are expected to maintain professionalism and integrity.

At or before the start of graduate study, normally at the beginning of Autumn Quarter, each student is assigned an advisor: a member of our faculty who provides research advice and guidance in course selection and in exploring academic opportunities and professional pathways. A significant advising milestone is the M.S. Program Proposal that each student completes at the end of their first quarter.

The department’s graduate handbook provides information and suggested timelines for advising meetings. Typically, research M.S. students meet with their advisor on a twice weekly basis, once individually and once as part of the research group meeting. If a meeting is not possible, the student should send the advisor a brief email highlighting his/her activities for the week. Usually, the same faculty member serves as program advisor for the duration of master’s study, but the handbook does describe a process for formal advisor changes.

In addition, the Director of Graduate Studies (DGS) meets with all the master’s students at the start of the first year and is available during the academic year by email and during office hours.

Students are expected to have a discussion with their advisor during or before the first week of each quarter to agree upon the courses that the student plans to take that quarter. Advisors formally approve the study list in person or by email.

The department’s student services office is also an important part of the master’s advising team. The student services office informs students and advisors about University and department requirements, procedures, and opportunities, and it maintains the official records of advising assignments and approvals.

Finally, graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program.

Ph.D. Student Advising

The Department of Energy Resources Engineering is committed to providing academic advising in support of doctoral student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the advisor and the advisee. As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual understanding. Both the advisor and the advisee are expected to maintain professionalism and integrity.

Faculty advisors guide students in key areas such as selecting courses, designing and conducting research, developing teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways. The department’s graduate handbook provides information and suggested timelines for advising meetings in the different stages of the doctoral program. If a meeting is not possible, the student should send the advisor a brief email highlighting his/her activities for the week. Typically, Ph.D. students meet with their advisor on a twice weekly basis, once individually and once as part of the research group meeting.

At least once per year, either formally or informally, students and advisors are expected to review the student’s progress towards completion of their research and their degree. Such discussions may include other members of the student’s research committee, either together or individually. A formal meeting of the full committee, which may be useful if the student and advisor differ in their assessment of research progress and goals, can be called by either the student or the advisor.

Ph.D. students are initially assigned a research advisor prior to or on arrival at Stanford. This faculty member provides initial guidance in course selection, in exploring academic opportunities and professional pathways, and in identifying doctoral research opportunities. Ultimately the advisor directs the student’s dissertation. Usually, the same faculty member serves as advisor for the duration of Ph.D. study, but the handbook does describe a process for formal advisor changes.

Most students have an advisor from among the primary faculty members of the department. However, the research advisor may be a faculty member from another Stanford department who is familiar with supervising doctoral students and able to provide both advising and funding for the duration of the doctoral program. When the research advisor is from outside the department, the student must also identify a program advisor from the department’s primary faculty to provide guidance on departmental requirements and opportunities.

Students are expected to have a discussion with their advisor during or before the first week of each quarter, to agree upon the courses that the student plans to take that quarter. Advisors formally approve the study list in person or by email.

The Director of Graduate Studies (DGS) meets with all doctoral students at the start of the first year, and is available during the academic year by email and during office hours. The department’s student services office is also an important part of the doctoral advising team: it informs students and advisors about University and department requirements, procedures, and opportunities, and it maintains the official records of advising assignments and approvals. Students are encouraged to talk with the DGS and the student services office for guidance in working with their advisor(s).

The department's doctoral students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program.

Emeriti: (Professors) Khalid Aziz, Franklin M. Orr, Jr.

Chair: Hamdi Tchelepi

Director of Graduate Studies: Roland N. Horne

Director of Undergraduate Studies: Anthony R. Kovscek

Professors: Sally M. Benson, Louis J. Durlofsky, Margot Gerritsen, Roland N. Horne, Anthony R. Kovscek, Tapan Mukerji, Daniel M. Tartakovsky, Hamdi Tchelepi

Associate Professors: Inês Azevedo, Adam Brandt

Assistant Professors: Ilenia Battiato, Simona Onori

Courtesy Professors: Stephan A. Graham, Mark Jacobson

Adjunct Faculty: Alan Burnham, David Danielson, Warren K. Kourt, Jonathan Lilien, Robert G. Lindblom, Joel Moxley, Kiran Pande, Richard Sears, Marco R. Thiele, Denis V. Voskov

Visiting Professor: Kozo Sato

Courses

ENERGY 20N. Technology in the Greenhouse. 3 Units.
The evidence that human activities are changing the climate is overwhelming. Energy use is woven throughout the fabric of modern societies, and energy systems are also a primary way that humans interact with the global Earth systems like climate. We know enough about the potential impacts of climate change to see that we need to transform the world¿s energy systems to a much cleaner set of technologies with much lower greenhouse gas emissions. Economies that use energy in a clean, cost-effective way will be much more competitive in the future. The clean energy transition is now underway, with reductions in coal use and rapid growth in solar and wind deployment, but there is much more to do to limit the adverse impacts of climate change. This seminar explores technology options available to make the changes needed, in the developed and developing worlds. There is no shortage of energy available for our use. Instead, the challenge is to convert those energy resources into services like electricity and transportation, and that conversion requires technology, as well as policies and markets that enable innovation. The scale of the world¿s energy systems is dauntingly large, and we will need a well-diversified set of options to meet the challenge. Wind, solar, nuclear, carbon capture and storage for fossil fuel use, modified agriculture, electric (and automated) vehicles, advanced air conditioning, and many other technology options exist. We will consider these technologies and ask what barriers will have to be addressed if they are to be deployed at a scale large enough to reduce the impact climate change. The format will be discussions of technologies and their potential with a project and student presentations toward the end of the quarter.

ENERGY 30N. Busting Energy Myths. 3 Units.
Energy myths and misconceptions to better equip participants to understand a pathway for global energy transformation. Key concepts developed and employed include energy [kinetic, potential, chemical, thermal, etc.], power, heat, renewables, efficiency, transmission, and life cycle analysis. Throughout this seminar groups of students are challenged with "energy myths" and their task is to deconstruct these myths and convince their classmates in oral presentations that they have indeed done so. Emphasis is on critical and analytical thinking, problem solving and presentation.

ENERGY 73. Energy Policy in California and the West. 1 Unit.
This seminar provides an in-depth analysis of the role of California state agencies and Western energy organizations in driving energy policy development, technology innovation, and market structures, in California, the West and internationally. The course covers three areas: 1) roles and responsibilities of key state agencies and Western energy organizations; 2) current and evolving energy and climate policies; and 3) development of the 21st century electricity system in California and the West. The seminar will also provide students a guideline of what to expect in professional working environment.
Same as: CEE 263G, POLISCI 73, PUBLPOL 73

ENERGY 101. Energy and the Environment. 3 Units.
Energy use in modern society and the consequences of current and future energy use patterns. Case studies illustrate resource estimation, engineering analysis of energy systems, and options for managing carbon emissions. Focus is on energy definitions, use patterns, resource estimation, pollution. Recommended: MATH 21 or 42.
Same as: EARTHSYS 101

ENERGY 101A. Energizing California. 1 Unit.
A weekend field trip featuring renewable and nonrenewable energy installations in Northern California. Tour geothermal, bioenergy, and natural gas field sites with expert guides from the Department of Energy Resources Engineering. Requirements: One campus meeting and weekend field trip. Enrollment limited to 25. Freshman have first choice.

ENERGY 102. Fundamentals of Renewable Power. 3 Units.
Do you want a much better understanding of renewable power technologies? Did you know that wind and solar are the fastest growing forms of electricity generation? Are you interested in hearing about the most recent, and future, designs for green power? Do you want to understand what limits power extraction from renewable resources and how current designs could be improved? This course dives deep into these and related issues for wind, solar, biomass, geothermal, tidal and wave power technologies. We welcome all student, from non-majors to MBAs and grad students. If you are potentially interested in an energy or environmental related major, this course is particularly useful. Recommended: Math 21 or 42.
Same as: EARTHSYS 102

ENERGY 104. Sustainable Energy for 9 Billion. 3 Units.
This course explores the global transition to a sustainable global energy system. We will formulate and program simple models for future energy system pathways. We will explore the drivers of global energy demand and carbon emissions, as well as the technologies that can help us meet this demand sustainably. We will consider constraints on the large-scale deployment of technology and difficulties of a transition at large scales and over long time periods. Assignments will focus on building models of key aspects of the energy transition, including global, regional and sectoral energy demand and emissions as well as economics of change. Prerequisites: students should be comfortable with calculus and linear algebra (e.g. Math 20, Math 51) and be familiar with computer programming (e.g. CS106A, CS106B). We will use the Python programming language to build our models.
Same as: ENERGY 206

ENERGY 110. Engineering Economics. 3 Units.
The success of energy projects and companies is judged by technical, economic and financial criteria. This course will introduce concepts of engineering economy, e.g., time value of money, life cycle costs and financial metrics, and explore their application to the business of energy. We will use case studies, business school cases and possibly industry guest lecturers. Examples from the hydrocarbon businesses that dominate energy today will provide the framework for the analysis of both conventional and renewable energy.

ENERGY 112. Exploring Geosciences with MATLAB. 1-3 Unit.
How to use MATLAB as a tool for research and technical computing, including 2-D and 3-D visualization features, numerical capabilities, and toolboxes. Practical skills in areas such as data analysis, regressions, optimization, spectral analysis, differential equations, image analysis, computational statistics, and Monte Carlo simulations. Emphasis is on scientific and engineering applications. Offered every year, autumn quarter.
Same as: GEOPHYS 112

ENERGY 118. Safety and Environmental Aspects of Energy Production. 3 Units.
This course introduces safety, environmental and regulatory aspects of energy development and production. Students will learn about personal and process safety management in energy projects, as well as major State and Federal laws and regulatory programs governing oil and gas, and renewables in the US. Lectures will introduce and explain concepts of safety, regulation, environment, and sustainability, further illustrated through discussion of case studies from the global energy industry. Many examples come from oil and gas because of the maturity of that industry and parallels with renewable energy will be discussed.
Same as: ENERGY 218

ENERGY 120. Fundamentals of Petroleum Engineering. 3 Units.
Lectures, problems, field trip. Engineering topics in petroleum recovery; origin, discovery, and development of oil and gas. Chemical, physical, and thermodynamic properties of oil and natural gas. Material balance equations and reserve estimates using volumetric calculations. Gas laws. Single phase and multiphase flow through porous media.
Same as: ENGR 120

ENERGY 121. Fundamentals of Multiphase Flow. 3 Units.
Multiphase flow in porous media. Wettability, capillary pressure, imbibition and drainage, Leverett J-function, transition zone, vertical equilibrium. Relative permeabilities, Darcy's law for multiphase flow, fractional flow equation, effects of gravity, Buckley-Leverett theory, recovery predictions, volumetric linear scaling, JBN and Jones-Rozelle determination of relative permeability. Frontal advance equation, Buckley-Leverett equation as frontal advance solution, tracers in multiphase flow, adsorption, three-phase relative permeabilities.
Same as: ENERGY 221

ENERGY 123. When Technology Meets Reality; An In-depth Look at the Deepwater Horizon Blowout and Oil Spill. 1 Unit.
The Deepwater Horizon blowout and spill in April 2010 occurred on one of the most advanced deepwater drilling rigs in the world operated by one of the most experienced companies. In this course we will look at and discuss the technologies and management practices involved in deepwater drilling and discuss how an accident like this happens and what could have been done differently to avoid it. We will focus on the Horizon and also look briefly at other high profile industrial and technological accidents.

ENERGY 130. Well Log Analysis I. 3 Units.
For earth scientists and engineers. Interdisciplinary, providing a practical understanding of the interpretation of well logs. Lectures, problem sets using real field examples: methods for evaluating the presence of hydrocarbons in rock formations penetrated by exploratory and development drilling. The fundamentals of all types of logs, including electric and non-electric logs.

ENERGY 141. Seismic Reservoir Characterization. 3-4 Units.
(Same as GP241) Practical methods for quantitative characterization and uncertainty assessment of subsurface reservoir models integrating well-log and seismic data. Multidisciplinary combination of rock-physics, seismic attributes, sedimentological information and spatial statistical modeling techniques. Student teams build reservoir models using limited well data and seismic attributes typically available in practice, comparing alternative approaches. Software provided (SGEMS, Petrel, Matlab). Offered every other year.nRecommended: ERE240/260, or GP222/223, or GP260/262 or GES253/257; ERE246, GP112.
Same as: ENERGY 241, GEOPHYS 241A

ENERGY 146. Reservoir Characterization and Flow Modeling with Outcrop Data. 3 Units.
Course gives an overview of concepts from geology and geophysics relevant for building subsurface reservoir models. Includes a required 1-day field trip and hands-on lab exercises. Target audience: MS and 1st year PhD students in PE/ERE/GS with little or no background in geology or geophysics. Topics include: basin and petroleum systems, depositional settings, deformation and diagenesis, introduction to reflection seismic data, rock and fluid property measurements, geostatistics, and flow in porous media.
Same as: ENERGY 246, GEOLSCI 246

ENERGY 153. Carbon Capture and Sequestration. 3-4 Units.
CO2 separation from syngas and flue gas for gasification and combustion processes. Transportation of CO2 in pipelines and sequestration in deep underground geological formations. Pipeline specifications, monitoring, safety engineering, and costs for long distance transport of CO2. Comparison of options for geological sequestration in oil and gas reservoirs, deep unmineable coal beds, and saline aquifers. Life cycle analysis.
Same as: ENERGY 253

ENERGY 155. Undergraduate Report on Energy Industry Training. 1-3 Unit.
On-the-job practical training under the guidance of on-site supervisors. Required report detailing work activities, problems, assignments and key results. Prerequisite: written consent of instructor.

ENERGY 160. Uncertainty Quantification in Data-Centric Simulations. 3 Units.
This course provides a brief survey of mathematical methods for uncertainty quantification. It highlights various issues, techniques and practical tools available for modeling uncertainty in quantitative models of complex dynamic systems. Specific topics include basic concepts in probability and statistics, spatial statistics (geostatistics and machine learning), Monte Carlo simulations, global and local sensitivity analyses, surrogate models, and computational alternatives to Monte Carlo simulations (e.g., quasi-MC, moment equations, the method of distributions, polynomial chaos expansions). Prerequisites: algebra (CME 104 or equivalent), introductory statistics course (CME 106 or equivalent).
Same as: ENERGY 260

ENERGY 167. Engineering Valuation and Appraisal of Energy Assets and Projects. 3 Units.
Appraisal of development and remedial work on oil and gas wells; appraisal of producing properties; estimation of productive capacity, reserves; operating costs, depletion, and depreciation; value of future profits, taxation, fair market value; original or guided research problems on economic topics with report. Prerequisite: consent of instructor.
Same as: ENERGY 267

ENERGY 171. Energy Infrastructure, Technology and Economics. 3 Units.
Oil and gas represents more than 50% of global primary energy. In delivering energy at scale, the industry has developed global infrastructure with supporting technology that gives it enormous advantages in energy markets; this course explores how the oil and gas industry operates. From the perspective of these established systems and technologies, we will look at the complexity of energy systems, and will consider how installed infrastructure enables technology development and deployment, impacts energy supply, and how existing infrastructure and capital invested in fossil energy impacts renewable energy development. Prerequisites: Energy 101 and 102 or permission of instructor.
Same as: ENERGY 271

ENERGY 175. Well Test Analysis. 3 Units.
Lectures, problems. Application of solutions of unsteady flow in porous media to transient pressure analysis of oil, gas, water, and geothermal wells. Pressure buildup analysis and drawdown. Design of well tests. Computer-aided interpretation.

ENERGY 180. Oil and Gas Production Engineering. 3 Units.
Design and analysis of production systems for oil and gas reservoirs. Topics: well completion, single-phase and multi-phase flow in wells and gathering systems, artificial lift and field processing, well stimulation, inflow performance. Prerequisite: 120.
Same as: ENERGY 280

ENERGY 191. Optimization of Energy Systems. 3-4 Units.
Introductory mathematical programming and optimization using examples from energy industries. Emphasis on problem formulation and solving, secondary coverage of algorithms. Problem topics include optimization of energy investment, production, and transportation; uncertain and intermittent energy resources; energy storage; efficient energy production and conversion. Methods include linear and nonlinear optimization, as well as multi-objective and goal programming. Tools include Microsoft Excel and AMPL mathematical programming language. Prerequisites: MATH 20, 41, or MATH 51, or consent of instructor. Programming experience helpful (e.g,, CS 106A, CS 106B).
Same as: ENERGY 291

ENERGY 192. Undergraduate Teaching Experience. 1-3 Unit.
Leading field trips, preparing lecture notes, quizzes under supervision of the instructor. May be repeated for credit.

ENERGY 193. Undergraduate Research Problems. 1-3 Unit.
Original and guided research problems with comprehensive report. May be repeated for credit.

ENERGY 194. Special Topics in Energy and Mineral Fluids. 1-3 Unit.
May be repeated for credit.

ENERGY 199. Senior Project and Seminar in Energy Resources. 3-4 Units.
Individual or group capstone project in Energy Resources Engineering. Emphasis is on report preparation. May be repeated for credit.

ENERGY 201. Laboratory Measurement of Reservoir Rock Properties. 3 Units.
In this course, students will learn methods for measuring reservoir rock properties. Techniques covered include core preservation and sample preparation; Rock petrography; Interfacial tension of fluids; Measurement of contact angles of fluids on reservoir media; Capillary pressure measurement and interpretation; Absolute and effective porosities; Absolute permeability; Multiphase flow including relative permeability and residual saturation. The class will be 1 3-hour lecture/lab per week, with readings and weekly assignments. A field trip to a professional core characterization lab may be included.

ENERGY 203. Stanford Climate Ventures. 1-3 Unit.
Solving the global climate challenge will require the creation and successful scale-up of hundreds of new ventures. This project-based course provides a launchpad for the development and creation of transformational climate ventures and innovation models. Interdisciplinary teams will research, analyze, and develop detailed launch plans for high-impact opportunities in the context of the new climate venture development framework offered in this course. Throughout the quarter, teams will complete 70+ interviews with customers, sector experts, and other partners in the emerging climatetech ecosystem, with introductions facilitated by the teaching team's unique networks in this space. Please see the course website scv.stanford.edu for more information and alumni highlights. Project lead applications are due by December 11 through tinyurl.com/scvprojectlead. Students interested in joining a project team, please briefly indicate your interest in the course at tinyurl.com/scvgeneralinterest.

ENERGY 204. Achieving Universal Energy Access by 2030: Can it be done?. 2-3 Units.
Today 1.2 billion people have no access to electricity; many more don't have power that is reliable. Activities the developed world counts on for economic growth are severely limited where there isn't reliable electricity. Cost reductions in distributed, renewable energy generation and battery storage technologies are creating opportunities to bring affordable power to communities that have never had it. This course will examine what will need to be in place so that electricity can reach everyone by 2030.

ENERGY 205. Hydrogen Economy. 1 Unit.
This is a seminar course on the hydrogen economy as a critical piece of the global energy transformation. This course will introduce the unique characteristics of hydrogen, its potential role in decarbonizing the global energy system, and how it compares to other alternative and complementary solutions. We will cover the main ideas/themes of how hydrogen is made, transported and stored, and used around the world through a series of lectures and guest speakers.

ENERGY 206. Sustainable Energy for 9 Billion. 3 Units.
This course explores the global transition to a sustainable global energy system. We will formulate and program simple models for future energy system pathways. We will explore the drivers of global energy demand and carbon emissions, as well as the technologies that can help us meet this demand sustainably. We will consider constraints on the large-scale deployment of technology and difficulties of a transition at large scales and over long time periods. Assignments will focus on building models of key aspects of the energy transition, including global, regional and sectoral energy demand and emissions as well as economics of change. Prerequisites: students should be comfortable with calculus and linear algebra (e.g. Math 20, Math 51) and be familiar with computer programming (e.g. CS106A, CS106B). We will use the Python programming language to build our models.
Same as: ENERGY 104

ENERGY 212. Environmental Aspects of Oil and Gas Production. 1 Unit.
This course introduces students to the major environmental aspects of oil and gas production, including law, policy, regulation, impact assessment, and mitigation. Through readings, lectures, homework, in-class activities, and case studies, students learn about the major state/federal laws and regulatory programs governing oil and gas in the U.S., industry permitting and compliance strategies, and current public stakeholder issues/challenges (with a particular focus on climate change and water management). Emerging legislative/regulatory trends, advocacy approaches, and sustainability concepts also are explored.

ENERGY 214. The Global Price of Oil. 2 Units.
Understanding the current and future price of oil requires the synthesis of geologic, engineering, financial, geopolitical, and macroeconomic information. In this seminar, we will build a global supply curve for petroleum by studying the marginal and full-cycle production costs for each of the major resource categories. We will study how reserve classification varies globally, and how global petroleum resources and reserves have changed and are likely to change over time. We will further investigate how the time lag between resource discovery, project sanctioning, and full production will affect future supply. Finally, we will study the elasticity of oil demand and how that demand is likely to change over time as the developing world gets richer and as competition from other energy sources increases.

ENERGY 216. Entrepreneurship in Energy. 2 Units.
The combined forces of climate change, technological development, and geopolitics are disrupting the energy industry, yet the competitiveness and regulated nature of the mature markets for fuel, power, and materials have created meaningful barriers to entry for startup companies. In this case based course, students will study real energy startups to understand what challenges they have overcome and continue to face. Each week, the course will focus on a different company and the founder or CEO of that company will present. Topics will include advanced battery technologies, photovoltaic manufacturing, solar and wind project development, oil & gas exploration & production, advanced biofuels, electric vehicles, distributed power generation, and financing energy startups.

ENERGY 217. Research Seminar: Energy Development in the Emerging Economy. 2-3 Units.
Through this research project, students will dive into and gain firsthand experience on evaluating the efficacy of a portfolio of 34 energy technology start-up projects in emerging economies that encompasses a range of regions, energy sectors, and technologies. Student's will learn from each project's unique experiences, and gather critical data that may help support the success of future similar endeavors. Some questions students will be looking to answer include (1) Was the project able to accomplish its goal(s)? (2) Are there common success factors or similar roadblocks? (3) Is the technology and/or solution still effective and operational?nPrerequisite: submit survey https://precourt.typeform.com/to/NdtU0Z and permission of instructor.

ENERGY 218. Safety and Environmental Aspects of Energy Production. 3 Units.
This course introduces safety, environmental and regulatory aspects of energy development and production. Students will learn about personal and process safety management in energy projects, as well as major State and Federal laws and regulatory programs governing oil and gas, and renewables in the US. Lectures will introduce and explain concepts of safety, regulation, environment, and sustainability, further illustrated through discussion of case studies from the global energy industry. Many examples come from oil and gas because of the maturity of that industry and parallels with renewable energy will be discussed.
Same as: ENERGY 118

ENERGY 221. Fundamentals of Multiphase Flow. 3 Units.
Multiphase flow in porous media. Wettability, capillary pressure, imbibition and drainage, Leverett J-function, transition zone, vertical equilibrium. Relative permeabilities, Darcy's law for multiphase flow, fractional flow equation, effects of gravity, Buckley-Leverett theory, recovery predictions, volumetric linear scaling, JBN and Jones-Rozelle determination of relative permeability. Frontal advance equation, Buckley-Leverett equation as frontal advance solution, tracers in multiphase flow, adsorption, three-phase relative permeabilities.
Same as: ENERGY 121

ENERGY 222. Advanced Reservoir Engineering. 3 Units.
Lectures, problems. General flow equations, tensor permeabilities, steady state radial flow, skin, and succession of steady states. Injectivity during fill-up of a depleted reservoir, injectivity for liquid-filled reservoirs. Flow potential and gravity forces, coning. Displacements in layered reservoirs. Transient radial flow equation, primary drainage of a cylindrical reservoir, line source solution, pseudo-steady state. Prerequisite: 221.

ENERGY 223. Reservoir Simulation. 3-4 Units.
Fundamentals of petroleum reservoir simulation. Equations for multicomponent, multiphase flow between gridblocks comprising a petroleum reservoir. Relationships between black-oil and compositional models. Techniques for developing black-oil, compositional, thermal, and dual-porosity models. Practical considerations in the use of simulators for predicting reservoir performance. Class project. Prerequisite: 221 and 246, or consent of instructor. Recommended: CME 206.

ENERGY 224. Advanced Reservoir Simulation. 3 Units.
Topics include modeling of complex wells, coupling of surface facilities, compositional modeling, dual porosity models, treatment of full tensor permeability and grid nonorthogonality, local grid refinement, higher order methods, streamline simulation, upscaling, algebraic multigrid solvers, unstructured grid solvers, history matching, other selected topics. Prerequisite: 223 or consent of instructor. May be repeated for credit.

ENERGY 225. Theory of Gas Injection Processes. 3 Units.
Lectures, problems. Theory of multicomponent, multiphase flow in porous media. Miscible displacement: diffusion and dispersion, convection-dispersion equations and its solutions. Method of characteristic calculations of chromatographic transport of multicomponent mixtures. Development of miscibility and interaction of phase behavior with heterogeneity. May be repeated for credit. Prerequisite: CME 200.

ENERGY 226. Thermal Recovery Methods. 3 Units.
Theory and practice of thermal recovery methods: steam drive, cyclic steam injections, and in situ combustion. Models of combined mass and energy transport. Estimates of heated reservoir volume and oil recovery performance. Wellbore heat losses, recovery production, and field examples.

ENERGY 227. Enhanced Oil Recovery. 3 Units.
The physics, theories, and methods of evaluating chemical, miscible, and thermal enhanced oil recovery projects. Existing methods and screening techniques, and analytical and simulation based means of evaluating project effectiveness. Dispersion-convection-adsorption equations, coupled heat, and mass balances and phase behavior provide requisite building blocks for evaluation.

ENERGY 230. Advanced Topics in Well Logging. 3 Units.
State of the art tools and analyses; the technology, rock physical basis, and applications of each measurement. Hands-on computer-based analyses illustrate instructional material. Guest speakers on formation evaluation topics. Prerequisites: 130 or equivalent; basic well logging; and standard practice and application of electric well logs.

ENERGY 240. Data science for geoscience. 3 Units.
This course provides an overview of the most relevant areas of data science (applied statistics, machine learning & computer vision) to address geoscience challenges, questions and problems. Using actual geoscientific research questions as background, principles and methods of data scientific analysis, modeling, and prediction are covered. Data science areas covered are: extreme value statistics, multi-variate analysis, factor analysis, compositional data analysis, spatial information aggregation models, spatial estimation, geostatistical simulation, treating data of different scales of observation, spatio-temporal modeling (geostatistics). Application areas covered are: process geology, hazards, natural resources. Students are encouraged to participate actively in this course by means of their own data science research challenge or question.
Same as: EARTHSYS 240, ESS 239, GEOLSCI 240

ENERGY 241. Seismic Reservoir Characterization. 3-4 Units.
(Same as GP241) Practical methods for quantitative characterization and uncertainty assessment of subsurface reservoir models integrating well-log and seismic data. Multidisciplinary combination of rock-physics, seismic attributes, sedimentological information and spatial statistical modeling techniques. Student teams build reservoir models using limited well data and seismic attributes typically available in practice, comparing alternative approaches. Software provided (SGEMS, Petrel, Matlab). Offered every other year.nRecommended: ERE240/260, or GP222/223, or GP260/262 or GES253/257; ERE246, GP112.
Same as: ENERGY 141, GEOPHYS 241A

ENERGY 246. Reservoir Characterization and Flow Modeling with Outcrop Data. 3 Units.
Course gives an overview of concepts from geology and geophysics relevant for building subsurface reservoir models. Includes a required 1-day field trip and hands-on lab exercises. Target audience: MS and 1st year PhD students in PE/ERE/GS with little or no background in geology or geophysics. Topics include: basin and petroleum systems, depositional settings, deformation and diagenesis, introduction to reflection seismic data, rock and fluid property measurements, geostatistics, and flow in porous media.
Same as: ENERGY 146, GEOLSCI 246

ENERGY 251. Thermodynamics of Equilibria. 3 Units.
Lectures, problems. The volumetric behavior of fluids at high pressure. Equation of state representation of volumetric behavior. Thermodynamic functions and conditions of equilibrium, Gibbs and Helmholtz energy, chemical potential, fugacity. Phase diagrams for binary and multicomponent systems. Calculation of phase compositions from volumetric behavior for multicomponent mixtures. Experimental techniques for phase-equilibrium measurements. May be repeated for credit.

ENERGY 252. Rock Physics. 3 Units.
Geophysical methods are used to image and characterize regions of the subsurface to explore for, evaluate and manage Earth resources (water and energy). A rock physics relationship is required to transform measured geophysical properties to the material properties of interest. Starting with the theoretical framework, we will explore the development of the rock physics transform from the laboratory to the field scale. Electrical and elastic properties and NMR. Grading based on four 2-week assignments.
Same as: GEOPHYS 262

ENERGY 253. Carbon Capture and Sequestration. 3-4 Units.
CO2 separation from syngas and flue gas for gasification and combustion processes. Transportation of CO2 in pipelines and sequestration in deep underground geological formations. Pipeline specifications, monitoring, safety engineering, and costs for long distance transport of CO2. Comparison of options for geological sequestration in oil and gas reservoirs, deep unmineable coal beds, and saline aquifers. Life cycle analysis.
Same as: ENERGY 153

ENERGY 255. Master's Report on Energy Industry Training. 1-3 Unit.
On-the-job training for master's degree students under the guidance of on-site supervisors. Students submit a report detailing work activities, problems, assignments, and key results. May be repeated for credit. Prerequisite: consent of adviser.

ENERGY 259. Presentation Skills. 1 Unit.
For teaching assistants in Energy Resources Engineering. Five two-hour sessions in the first half of the quarter. Awareness of different learning styles, grading philosophies, fair and efficient grading, text design; presentation and teaching skills, PowerPoint slide design; presentation practice in small groups. Taught in collaboration with the Center for Teaching and Learning.

ENERGY 260. Uncertainty Quantification in Data-Centric Simulations. 3 Units.
This course provides a brief survey of mathematical methods for uncertainty quantification. It highlights various issues, techniques and practical tools available for modeling uncertainty in quantitative models of complex dynamic systems. Specific topics include basic concepts in probability and statistics, spatial statistics (geostatistics and machine learning), Monte Carlo simulations, global and local sensitivity analyses, surrogate models, and computational alternatives to Monte Carlo simulations (e.g., quasi-MC, moment equations, the method of distributions, polynomial chaos expansions). Prerequisites: algebra (CME 104 or equivalent), introductory statistics course (CME 106 or equivalent).
Same as: ENERGY 160

ENERGY 262. Physics of Wind Energy. 3 Units.
Formerly CEE 261. An introduction to the analysis and modeling of wind energy resources and their extraction. Topics include the physical origins of atmospheric winds; vertical profiles of wind speed and turbulence over land and sea; the wind energy spectrum and its modification by natural topography and built environments; theoretical limits on wind energy extraction by wind turbines and wind farms; modeling of wind turbine aerodynamics and wind farm performance. Final project will focus on development of a new wind energy technology concept. Prerequisites: CEE 262A or ME 351A.
Same as: CEE 261B, ME 262

ENERGY 263. Introduction to Quantitative Methods for Energy Decisions. 3 Units.
This course provides students from various backgrounds with knowledge of the principles and quantitative methods of decision analysis and policy analysis to tackle interdisciplinary questions in the context of sustainable energy systems. We consider engineering analysis, decision analysis and economic analysis in the formulation of answers to address energy system problems. We will use methods such as life-cycle assessment, benefit-cost and cost-effectiveness analysis, microeconomics, distributional metrics, risk analysis methods, sensitivity and uncertainty analysis, multi-attribute utility theory, and simulation and optimization. The integration of uncertainty into formal methods is a fundamental component of the course.
Same as: CEE 263H

ENERGY 266. Town Hall Meeting. 1 Unit.
This course will offer students the opportunity to structure and present a simulated public meeting on a current topic involving energy production and its effects on a local community. Students will choose a topic and develop a town hall meeting event that reflects the range of concerns of public, corporate, and regulatory stakeholders. The meeting will be presented on campus to the Stanford Community and the general public. Students will have the opportunity to hone their skills in delivering persuasive oral arguments, critical thinking, and leadership.
Same as: Simulated

ENERGY 267. Engineering Valuation and Appraisal of Energy Assets and Projects. 3 Units.
Appraisal of development and remedial work on oil and gas wells; appraisal of producing properties; estimation of productive capacity, reserves; operating costs, depletion, and depreciation; value of future profits, taxation, fair market value; original or guided research problems on economic topics with report. Prerequisite: consent of instructor.
Same as: ENERGY 167

ENERGY 269. Geothermal Reservoir Engineering. 3 Units.
Conceptual models of heat and mass flows within geothermal reservoirs. The fundamentals of fluid/heat flow in porous media; convective/conductive regimes, dispersion of solutes, reactions in porous media, stability of fluid interfaces, liquid and vapor flows. Interpretation of geochemical, geological, and well data to determine reservoir properties/characteristics. Geothermal plants and the integrated geothermal system.

ENERGY 271. Energy Infrastructure, Technology and Economics. 3 Units.
Oil and gas represents more than 50% of global primary energy. In delivering energy at scale, the industry has developed global infrastructure with supporting technology that gives it enormous advantages in energy markets; this course explores how the oil and gas industry operates. From the perspective of these established systems and technologies, we will look at the complexity of energy systems, and will consider how installed infrastructure enables technology development and deployment, impacts energy supply, and how existing infrastructure and capital invested in fossil energy impacts renewable energy development. Prerequisites: Energy 101 and 102 or permission of instructor.
Same as: ENERGY 171

ENERGY 273. Special Topics in Energy Resources Engineering. 1-3 Unit.
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ENERGY 280. Oil and Gas Production Engineering. 3 Units.
Design and analysis of production systems for oil and gas reservoirs. Topics: well completion, single-phase and multi-phase flow in wells and gathering systems, artificial lift and field processing, well stimulation, inflow performance. Prerequisite: 120.
Same as: ENERGY 180

ENERGY 281. Applied Mathematics in Reservoir Engineering. 3 Units.
The philosophy of the solution of engineering problems. Methods of solution of partial differential equations: Laplace transforms, Fourier transforms, wavelet transforms, Green's functions, and boundary element methods. Prerequisites: CME 204 or MATH 131, and consent of instructor.

ENERGY 282. Chemical Kinetics and Basin Modeling. 2-3 Units.
Students will explore the structure of sedimentary organic matter and the chemical and thermodynamic requirements for generating petroleum. A wide variety of thermal maturity indicators will be explored, paying particular attention to optical indicators and predictive kinetics of Tmax and %Ro. Students will understand the advantages and pitfalls of kinetic measurements in the lab. Hands-on exercises reinforce learning targets. An optional class project allows students to take the class for 3 units instead of 2. Course readings come from the literature and Burnham's textbook.
Same as: GEOLSCI 216, GEOPHYS 216

ENERGY 289. Multiscale Methods for Transport in Porous Media. 3 Units.
The concept of "tyranny of scales" in natural/engineered porous media refers to the disparity of temporal and spatial scales at which mass, momentum, and energy transport is best understood and at which predictions are needed for practical applications. Modeling approaches that incorporate process understanding at different temporal and spatial scales are often necessary to improve our predictive capabilities of natural and engineered porous media.nThe course focuses on the fundamental understanding of multiscale systems and corresponding modeling tools to analyze them.

ENERGY 291. Optimization of Energy Systems. 3-4 Units.
Introductory mathematical programming and optimization using examples from energy industries. Emphasis on problem formulation and solving, secondary coverage of algorithms. Problem topics include optimization of energy investment, production, and transportation; uncertain and intermittent energy resources; energy storage; efficient energy production and conversion. Methods include linear and nonlinear optimization, as well as multi-objective and goal programming. Tools include Microsoft Excel and AMPL mathematical programming language. Prerequisites: MATH 20, 41, or MATH 51, or consent of instructor. Programming experience helpful (e.g,, CS 106A, CS 106B).
Same as: ENERGY 191

ENERGY 293. Energy storage and conversion: Solar Cells, Fuel Cells, Batteries and Supercapacitors. 3 Units.
This course provides an introduction and engineering exposure to energy storage and conversion systems and will cover the basic physics, chemistry and electrochemistry of solar cells, fuel cells, batteries and supercapacitors, state of the art of such technologies and recent developments. The course will also cover experimental methods and modeling tools for simulation and optimization aimed at characterizing efficiency and performance issues. Prerequisites: Equivalent coursework in thermodynamics, electronic properties, chemical principles, electricity, and magnetism.
Same as: EE 293

ENERGY 293B. Fundamentals of Energy Processes. 3 Units.
For seniors and graduate students. Covers scientific and engineering fundamentals of renewable energy processes involving heat. Thermodynamics, heat engines, solar thermal, geothermal, biomass. Recommended: MATH 19-21; PHYSICS 41, 43, 45.
Same as: EE 293B

ENERGY 293C. Energy from Wind and Water Currents. 3 Units.
This course focuses on the extraction of energy from wind, waves and tides.The emphasis in the course is technical leading to a solid understanding of established extraction systems and discussion of promising new technologies. We will also cover resource planning and production optimization through observations and computer simulations.

ENERGY 295. Electrochemical Energy Storage Systems: Modeling and Estimation. 3 Units.
The course focuses on modeling and estimation methods as necessary tools to extract the full potential from Lithium-ion batteries, specifically used in electrified vehicles. The complex nature of a battery system requires that a physics-based approach, in the form of electrochemical models, be used as a modeling platform to develop system-level control algorithms to allow designer to maximize batteries performance and longevity while guaranteeing safety operations. In this course, we will cover 1) first-principles methods to model battery dynamics, 2) electrochemical and control-oriented models, 3) estimation algorithms for real-time application. A formal exposure to state space analysis and estimation of dynamical systems will be given. Previously ENERGY 294. Prerequisites: Equivalent coursework in linear systems and control. Prior working knowledge of Matlab/Simulink¿ tools is assumed.

ENERGY 297. Fluid Mechanics and Heat Transfer. 3 Units.
Energy systems are multiphysics and multiscale in nature. This course addresses the quantitative understanding of fundamental physical processes that govern fluid flow and mass/heat transfer processes, critical to many energy systems. The course will cover conservation laws describing the dynamics of single phase flows, relevant to energy applications including, but not limited to, laminar flow solutions in pipes and ducts, Stokes flows (relevant to flow in porous media), potential and boundary layer flow theories (relevant to wind energy), heat and mass transport (relevant to geothermal and energy storage systems, reactive transport in the subsurface, CO2 sequestration). Although motivated by specific applications in the energy landscape, the course will be focused on fundamental principles and mathematical techniques to understand the basic physics underlying flow and transport processes.

ENERGY 300. Graduate Directed Reading. 1-7 Unit.
Independent studies under the direction of a faculty member for which academic credit may properly be allowed.

ENERGY 301. The Energy Seminar. 1 Unit.
Interdisciplinary exploration of current energy challenges and opportunities, with talks by faculty, visitors, and students. May be repeated for credit.
Same as: CEE 301, MS&E 494

ENERGY 308. Carbon Dioxide and Methane Removal, Utilization, and Sequestration. 1 Unit.
This is a seminar on carbon dioxide and methane removal, utilization, and sequestration options, and their role in decarbonizing the global energy system. This course will cover topics including the global carbon balance, utilizing atmospheric carbon in engineered solutions, recycling and sequestering fossil-based carbon, and enhancing natural carbon sinks. The multidisciplinary lectures and discussions will cover elements of technology, economics, policy and social acceptance, and will be led by a series of guest lecturers. Short group project on carbon solutions.
Same as: EARTHSYS 308, ENVRES 295, ESS 308, ME 308

ENERGY 309. Sustainable Energy Interdisciplinary Graduate Seminar. 1 Unit.
Graduate students will present their ongoing research to an audience of faculty and graduate students with a diversity of disciplinary perspectives regarding sustainable energy.
Same as: CEE 372, MS&E 495

ENERGY 351. ERE Master's Graduate Seminar. 1 Unit.
Current research topics. Presentations by guest speakers from Stanford and elsewhere. May be repeated for credit.

ENERGY 352. ERE PhD Graduate Seminar. 1 Unit.
Current research topics. Presentations by guest speakers from Stanford and elsewhere. May be repeated for credit.

ENERGY 355. Doctoral Report on Energy Industry Training. 1-3 Unit.
On-the-job training for doctoral students under the guidance of on-site supervisors. Students submit a report on work activities, problems, assignments, and results. May be repeated for credit. Prerequisite: consent of adviser.

ENERGY 359. Teaching Experience in Energy Resources Engineering. 1 Unit.
For TAs in Energy Resources Engineering. Course and lecture design and preparation; lecturing practice in small groups. Classroom teaching practice in an Energy Resources Engineering course for which the participant is the TA (may be in a later quarter). Taught in collaboration with the Center for Teaching and Learning.

ENERGY 360. Advanced Research Work in Energy Resources Engineering. 1-10 Unit.
Graduate-level work in experimental, computational, or theoretical research. Special research not included in graduate degree program. May be repeated for credit.

ENERGY 361. Master's Degree Research in Energy Resources Engineering. 1-6 Unit.
Experimental, computational, or theoretical research. Advanced technical report writing. Limited to 6 units total.nn (Staff).

ENERGY 362. Engineer's Degree Research in Energy Resources Engineering. 1-10 Unit.
Graduate-level work in experimental, computational, or theoretical research for Engineer students. Advanced technical report writing. Limited to 15 units total, or 9 units total if 6 units of 361 were previously credited.

ENERGY 363. Doctoral Degree Research in Energy Resources Engineering. 1-10 Unit.
Graduate-level work in experimental, computational, or theoretical research for Ph.D. students. Advanced technical report writing.

ENERGY 365. Special Research Topics in Energy Resources Engineering. 1-15 Unit.
Graduate-level research work not related to report, thesis, or dissertation. May be repeated for credit.

ENERGY 369. Practical Energy Studies. 1-3 Unit.
Students work on realistic industrial reservoir engineering problems. Focus is on optimization of production scenarios using secondary or tertiary recovery techniques. When possible, projects are conducted in direct collaboration with industry. May be repeated for credit.

ENERGY 801. TGR Project. 0 Units.
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ENERGY 802. TGR Dissertation. 0 Units.
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