

# ENERGY RESOURCES ENGINEERING (ENERGY)

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## **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 Oil and Gas Production. 3 Units.**

This course introduces safety, environmental and regulatory aspects of oil and gas development and production. Students will learn about personal and process safety management in oil and gas, as well as major State and Federal laws and regulatory programs governing oil and gas 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 oil and gas industry. 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. Recommended: 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.**

CO<sub>2</sub> separation from syngas and flue gas for gasification and combustion processes. Transportation of CO<sub>2</sub> in pipelines and sequestration in deep underground geological formations. Pipeline specifications, monitoring, safety engineering, and costs for long distance transport of CO<sub>2</sub>. 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](http://scv.stanford.edu) for more information and alumni highlights. Project lead applications are due by December 11 through [tinyurl.com/scvprojectlead](http://tinyurl.com/scvprojectlead). Students interested in joining a project team, please briefly indicate your interest in the course at [tinyurl.com/scvgeneralinterest](http://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 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 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?  
Prerequisite: submit survey <https://precourt.typeform.com/to/NdtU0Z> and permission of instructor.

**ENERGY 218. Safety and Environmental Aspects of Oil and Gas Production. 3 Units.**

This course introduces safety, environmental and regulatory aspects of oil and gas development and production. Students will learn about personal and process safety management in oil and gas, as well as major State and Federal laws and regulatory programs governing oil and gas 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 oil and gas industry. 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. Recommended: 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.**

CO<sub>2</sub> separation from syngas and flue gas for gasification and combustion processes. Transportation of CO<sub>2</sub> in pipelines and sequestration in deep underground geological formations. Pipeline specifications, monitoring, safety engineering, and costs for long distance transport of CO<sub>2</sub>. 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. The 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, CO<sub>2</sub> 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 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 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. (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 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 801. TGR Project. 0 Units.**

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**ENERGY 802. TGR Dissertation. 0 Units.**

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