ENERGY RESOURCES ENGINEERING (ENERGY)

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 transition to a sustainable energy system at large scales (national and global), and over long time periods (decades). Explores the drivers of global energy demand and the fundamentals of technologies that can meet this demand sustainably. Focuses on constraints affecting large-scale deployment of technologies, as well as inertial factors affecting this transition. Problems will involve modeling global energy demand, deployment rates for sustainable technologies, technological learning and economics of technical change. Recommended: ENERGY 101, 102.

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 the 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 120. Fundamentals of Petroleum Engineering. 3 Units.
Same as: ENGR 120

ENERGY 120A. Flow Through Porous Media Laboratory. 1 Unit.
Laboratory measurements of permeability and porosity in rocks. Applications to subsurface fluid mechanics. Course is intended as an accompaniment to Energy 120.
ENERGY 12SC. Water and Power in the Pacific Northwest: The Columbia River. 2 Units.
This seminar will explore the nature of and coupling between water and energy resources in the Pacific Northwest, using the Columbia River as our case study. We will explore the hydrologic, meteorologic, and geologic basis of water and energy resources, and the practical, social, environmental, economic, and political issues surrounding their development in the West. The Columbia River and its watershed provide a revealing prototype for examining these issues. A transnational, multi-state river with the largest residual populations of anadromous salmonids in the continental US, it provides a substantial fraction of the electrical energy produced in the Northwest (the Grand Coulee dam powerhouse on the Columbia is the largest-capacity hydropower facility in the US), it is a major bulk commodity transportation link to the interior West via its barge navigation system, it provides the water diversions supporting a large area of irrigated agriculture in Washington and Idaho, and its watershed is home to significant sources of solar and wind energy. We will use the Columbia to study water and energy resources, and especially their coupling, in the context of rapid climate change, ecosystem impacts, economics, and public policy.<br> We will begin with a week of classroom study and discussion on campus, preparing for the field portion of the seminar. We will then travel to the Columbia basin, spending approximately 10 days visiting a number of water and energy facilities across the watershed, e.g., solar, wind, and natural gas power plants; dams and reservoirs with their powerhouses, fish passage facilities, navigation locks, and flood-mitigation systems; an irrigation project; operation centers; and offices of regulatory agencies. We will meet with relevant policy experts and public officials, along with some of the stakeholders in the basin. Over the summer students will be responsible for assigned readings from several sources, including monographs, online materials, and recent news articles. During the trip, students will work in small groups to analyze and assess one aspect of the coupling between water and energy resources in the Northwest. The seminar will culminate in presentations on these analyses. Travel expenses during the seminar will be provided (except incidentals) by the Bill Lane Center for the American West and Sophomore College.

Same as: CEE 17SC, EARTHSYS 16SC, POLISCI 14SC

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.
Project addressing a reservoir management problem by studying an outcrop analog, constructing geostatistical reservoir models, and performing flow simulation. How to use outcrop observations in quantitative geological modeling and flow simulation. Relationships between disciplines. Weekend field trip.
Same as: ENERGY 246, GS 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

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 158. Bringing New Energy Technologies to Market: Optimizing Technology Push and Market Pull. 3 Units.
This research-based seminar will evaluate the impact of market interventions in commercializing four segments of our energy mix: wind, photovoltaics, lighting, and batteries. To accelerate the development of new technologies to reduce greenhouse gas emissions and improve national security, governments use policies like direct R&D funding, financial incentives or penalties, mandatory targets or caps, and performance standards to create market conditions that favor emerging technologies. Findings outlining the most effective mix of interventions over time will be submitted for publication. Enrollment limited to 12 graduate and co-term students. Those interested please email a paragraph to cathyzoi@stanford.edu by September 16, 2013 expressing why you want to take part and research experience you can bring to the seminar.

ENERGY 160. Modeling Uncertainty in the Earth Sciences. 3 Units.
Whether Earth Science modeling is performed on a local, regional or global scale, for scientific or engineering purposes, uncertainty is inherently present due to lack of data and lack of understanding of the underlying phenomena. This course highlights the various issues, techniques and practical tools available for modeling uncertainty of complex Earth systems as well as the impact uncertainty has on practical decisions for geo-engineering problems. The course focuses on practical breadth rather than theoretical depth. Topics covered are: the process of building models, sources of uncertainty, probabilistic techniques, spatial data analysis and geostatistics, grid and scale, spatio-temporal uncertainty, visualizing uncertainty in large dimensions, Monte Carlo simulation, sensitivity analysis, reducing uncertainty with data, value of information. Applications to both local (reservoir, aquifer) and global (climate) are covered through literature study. Extensive software use with SGEMS. Prerequisites: algebra (CME 104 or equivalent), introductory statistics course (CME 106 or equivalent).

ENERGY 167. Engineering Valuation and Appraisal of Oil and Gas Wells, Facilities, and Properties. 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 fuel 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 202. Petroleum Industry Performance Management. 1 Unit.
Coming up with the right technical solution is only the beginning, it
must be implemented. The art and science of Performance Management.
How to guarantee results with Leading and Lagging KPI’s (Key
Performance Indicators). Assessment using the FAIRTM Model (Focus,
Accountability, Involvement, Response). Operating RhythmTM: Business
Reviews, Boardwalks, One-Pagers, Handover, and Crew Talks. Project
management, implementation plans, milestones, and clear deliverables.
Sustainability. After Action Reviews (AAR’s). Continuous Improvement
(CI). Coaching GROW Model (Goal, Reality, Options, Will), The ABC
Model, Behavior, Consequence. Students will solve three Case Studies with these tools; the instructor will present the actual
solution, what worked, what didn’t, and why.

ENERGY 203. The Energy Transformation Collaborative. 1-2 Unit.
Solving the global energy 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 energy ventures and innovation models.
Interdisciplinary teams will research, analyze, and develop detailed
launch plans for high-impact opportunities in the context of the new
energy venture development framework offered in this course.

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 214. The Global Price of Oil. 1 Unit.
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 24 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/NdItU0Z and permission of instructor.

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. Injectorivity 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. May be repeated for credit. Prerequisite: 221.

ENERGY 223. Reservoir Simulation. 3-4 Units.
Fundamentals of petroleum reservoir simulation. Equations for 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, upsampling, 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.

ENERGY 226. Thermal Recovery Methods. 3 Units.
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 Helmholz 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 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.

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 267. Engineering Valuation and Appraisal of Oil and Gas Wells, Facilities, and Properties. 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.

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.

ENERGY 273. Special Topics in Energy Resources Engineering. 1-3 Unit.

ENERGY 274. Complex Analysis for Practical Engineering. 3 Units.
Complex analysis is closely related to potential theory, appearing in a variety of engineering disciplines, including flow dynamics, electrostatics, heat conduction and gravity fields. This course is devoted to explaining the fundamentals of complex analysis and instructing on how to develop mathematical tools to solve engineering problems in potential theory. Individual topics are lectured with motivating problems, so that students can understand why these subjects need to be covered and how these are applied to practical engineering problems.

Examine the physical processes operating in sedimentary basins by deriving the basic equations of fundamental, coupled geologic processes such as fluid flow and heat flow, deposition, compaction, mass conservation, and chemical reactions. Through hands-on computational exercises and instructor-provided "recipes," students will deconstruct the black box of basin modeling software. Students write their own codes (Matlab) as well as gain expertise in modern finite-element modeling software (PetroMod, COMSOL).

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.

ENERGY 285A. SUPRI-A Research Seminar: Enhanced Oil Recovery. 1 Unit.
Focused study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Current research in the SUPRI-A group. May be repeated for credit. Prerequisite: consent of instructor.
ENERGY 285B. SUPRI-B Research Seminar: Reservoir Simulation. 1 Unit.
Focused study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Current research in the SUPRI-B (reservoir simulation) program. May be repeated for credit. Prerequisite: consent of instructor.

ENERGY 285C. SUPRI-C Research Seminar: Gas Injection Processes. 1 Unit.
Study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Current research in the SUPRI-D well test analysis group. May be repeated for credit. Prerequisite: consent of instructor.

ENERGY 285D. SUPRI-D Research Seminar: Well Test Analysis. 1 Unit.
Study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Current research in the SUPRI-D well test analysis group. May be repeated for credit. Prerequisite: consent of instructor. (Horne).

ENERGY 285E. SCRF Research Seminar: Geostatistics and Reservoir Forecasting. 1 Unit.
Study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Current research in the SCRF (Stanford Center for Reservoir Forecasting) program. Prerequisite: consent of instructor.

ENERGY 285F. Geothermal Reservoir Engineering Research Seminar. 1 Unit.
Study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Current research in the geothermal energy group. Presentation required for credit. Prerequisite: consent of instructor.

ENERGY 285G. Smart Fields Research Seminar: Horizontal Well Technology. 1 Unit.
Study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. Current research in Smart Fields (productivity and injectivity of horizontal wells) program. Prerequisite: consent of instructor.

ENERGY 289A. Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution. 3-4 Units.
Operating principles and applications of emerging technological solutions to the energy demands of the world. The scale of global energy usage and requirements for possible solutions. Basic physics and chemistry of solar cells, fuel cells, and batteries. Performance issues, including economics, from the ideal device to the installed system. The promise of materials research for providing next generation solutions. Undergraduates register in 156 for 4 units; graduates register in 256 for 3 units.
Same as: EE 293A, MATSCI 156, MATSCI 256

ENERGY 289B. 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, or Math 41A, 42, PHYSICS 41, 43, 45. Same as: EE 293B

ENERGY 289C. 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. The course includes at least one weekend field trip, and may include experiment or seminar in wind tunnel and/or flume. Prerequisites: CEE 176B or EE 293B, programming experience, understanding of fluid mechanics, electrical systems, and engineering optimization.

ENERGY 295. Quantitative environmental assessment of energy systems. 1 Unit.
Graduate seminar on quantitative environmental assessment of energy technologies. Assessment methods for analyzing multi-device and multi-technology energy systems (e.g., full energy production pathways). Methodological coverage includes process-model life cycle assessment (LCA), energy embodied in materials, energy return on energy invested, and cumulative exergy consumption. Exploration of theoretical modeling of multi-technology systems using matrix formulations. Tools used include MATLAB and openLCA life cycle assessment software. Prerequisites: linear algebra and some programming experience helpful (e.g. CS 106A-B).

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

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 801. TGR Project. 0 Units.

ENERGY 802. TGR Dissertation. 0 Units.