RENEWABLE AND CLEAN ENERGY

Jamie Ervin, Department Chairperson

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Master of Science in Renewable and Clean Energy (RCL)

The program of study leading to the Master of Science in Renewable and Clean Energy degree, developed by the student in conjunction with her/his advisor, must include 30 semester hours. The program of study must include 18 or more semester hours of MEE/AEE/RCL credits and a minimum of three semester hours of mathematics. Students may pursue a thesis or non-thesis option. A thesis option requires six semester hours of RCL 599 Renewable and Clean Energy Thesis credits, which includes both an oral defense and a written thesis.

See also Master's Degree Requirements in the School of Engineering section in the catalog and consult with the advisor.

Minimum RCL/MEE/AEE		18
Minimum Mathematics		3
Thesis Option:		6
RCL 599	Renewable & Clean Energy Thesis	
Electives		3-9

Courses

RCL 507. Materials Advanced Energy Applications. 3 Hours
Successful long-term application of many advanced energy technologies is ultimately based on the utilization of materials in 'real world' environmental conditions. The physical/mechanical properties and application of various materials (i.e. superalloys, refractory metal alloys, ceramics) being employed in advanced energy applications are discussed. Several advanced energy technologies (i.e. fuel cells, nuclear energy, and others) are covered with emphasis on how the selection of advanced materials enhances their commercial application. Prerequisite(s): MAT 501 and MAT 502 or permission of instructor.

RCL 511. Advanced Thermodynamics. 3 Hours
Equilibrium, first law, second law, state principle, and zeroth law; development of entropy and temperature from availability concepts; chemical potential, chemical equilibrium, and phase equilibrium. Thermodynamics of irreversible processes; Onsager reciprocal relations; application of these concepts to direct energy conversion.

RCL 524. Electrochemical Power. 3 Hours
The course will cover fundamental as well as engineering aspects of fuel cell technology. Specifically, the course will cover basic principles of electrochemistry, electrical conductivity (electronic and ionic) of solids, and development/design of major fuel cells (alkaline, polymer electrolyte, phosphoric acid, molten carbonate, and solid oxide). A major part of the course will focus on solid oxide fuel cells (SOFC), as it is emerging to be dominant among various fuel cell technologies. The SOFC can readily and safely use many common hydrocarbon fuels such as natural gas, diesel, gasoline, alcohol, and coal gas. Prerequisite(s): (MEE 301, MEE 312) or permission of instructor.

RCL 533. Biofuel Production Processes. 3 Hours
This course will provide an overview of the range of fuels derived from biological materials and processes, with a focus on anaerobic digestion, bioethanol and biodiesel and production of synethetic fuel from biological materials. The course will include an overview of the biochemistry of energy production in biological systems, discussions of the economics and environmental sustainability of biofuels, and a review of reactor and separation systems concepts relevant to biofuel production. Prerequisite(s): EGR 202, CHM 123, or consent of instructor.

RCL 556. Energy Systems Engineering. 3 Hours
This course is aimed at providing fundamental knowledge of thermodynamics, fluid mechanics, and heat transfer in context of Energy Systems Engineering. A Just-in-Time approach to learning and applying these topics will be used. Projects will anchor all class activities. In addition to providing knowledge and experience of thermodynamics, fluid mechanics, and heat transfer, this course seeks to provide students the analysis skills necessary to determine the importance of energy conversion technologies, with special emphasis on energy efficiency and renewable energy (tidal, hydroelectric, wind, solar and geothermal).

RCL 557. Building Energy Informatics. 3 Hours
The focus of the course is the collection and analysis of energy data sets to reduce energy consumption and/or energy demand. Students will typically utilize monthly energy data from multiple buildings, real time energy data, and building energy audit data. Students will disaggregate/aggregate data to develop energy use benchmarks, identify priority buildings/actions for energy reduction, identify problems, and estimate savings. Programming in Matlab and an introduction to sql dbase management are covered.

RCL 561. Solar Energy Engineering. 3 Hours
This course will cover the theory, design, and application of two broad uses of solar energy: (i) direct thermal and (ii) electrical energy generation. The majority of the course will focus on thermal applications, with emphasis on system simulation and design for buildings and other systems. The course will expose students to the development and use of solar design and simulation tools. Most of the tools will be implemented in Excel and TRNSYS, but students are welcome to use other software tools such as Engineering Equation Solver (EES) or MATLAB. Some of the class time will be devoted to demonstrate the development and use of these tools to solve homework problems.

RCL 562. Geothermal Energy Engineering. 3 Hours
This course will cover the theory and design of the three broad uses of geothermal energy: (i) heat pump applications, (ii) direct uses, and (iii) electrical energy generation. The majority of the course will focus on heat pump applications, with emphasis on ground heat exchanger simulation and design for buildings and other systems. Closed-loop, open-loop, and hybrid geothermal heat pump systems will be examined. Heating, cooling, and electricity generating applications using hot geothermal reservoirs will also be discussed. The course will expose students to the development and use of geothermal design and simulation tools. Most of the tools will be implemented in Excel, but students are welcome to use other software tools such as Engineering Equation Solver (EES) or MATLAB. The course notes explain the development and use of these tools, which will be used to solve homework problems. Prerequisite(s): Undergraduate thermodynamics and heat transfer courses.

RCL 563. Wind Energy Engineering. 3 Hours
Introduction to wind energy engineering, including wind energy potential and its application to power generation. Topics include wind turbine components; turbine fluid dynamics and aerodynamics; turbine structures; turbine dynamics; wind turbine controls; fatigue; connection to the electric grid; maintenance; wind site assessment; wind economics; and wind power legal, environmental, and ethical issues. Prerequisite(s): Undergraduate fluid mechanics course.

RCL 564. Sustainable Energy Systems. 3 Hours
Survey of conventional fossil-fuel and renewable energy with an emphasis on system integration. Basic concepts of climate physics will be addressed along with estimates of fossil resources.

RCL 568. Internal Combustion Engines. 3 Hours
Study of combustion and energy release processes. Applications to spark and compression ignition, jet, rocket, and gas turbine engines. Special emphasis given to understanding of air pollution problems caused by internal combustion engines. Idealized and actual cycles are studied in preparation for laboratory testing of internal combustion engines.

RCL 569. Energy Efficient Buildings. 3 Hours
Provides knowledge and skills necessary to design and operate healthier, more comfortable, more productive, and less environmentally destructive buildings; A specific design target of E/3 (typical energy use divided by three) is established as a goal. Economic, thermodynamic, and heat transfer analyses are utilized. Extensive software development.

RCL 571. Design of Thermal Systems. 3 Hours
Integration of thermodynamics, heat transfer, engineering economics, and simulation and optimization techniques in a design framework. Topics include design methodology, energy analysis, heat exchanger networks, thermal-system simulation, and optimization techniques.

RCL 572. Design for Environment. 3 Hours
Emphasis on design for environment over the life cycle of a product or process, including consideration of mining, processing, manufacturing, use, and post-life stages. Course provides knowledge and experience in invention for the purpose of clean design, life cycle assessment strategies to estimate the environmental impact of products and processes, and cleaner manufacturing practices. Course includes a major design project.

RCL 573. Renewable Energy Systems. 3 Hours
Introduction to the impact of energy on the economy and environment. Engineering models of solar thermal and photovoltaic systems. Introduction to wind power. Fuel cells and renewable sources of hydrogen.

RCL 578. Energy Efficient Manufacturing. 3 Hours
This course presents a systematic approach for improving energy efficiency in the manufacturing sector. Current patterns of manufacturing energy use, the need for increased energy efficiency, and models for sustainable manufacturing are reviewed. The lean-energy paradigm is applied to identify energy efficiency opportunities in industrial electrical, lighting, space conditioning, motor drive, compressed air, process heating, process cooling, and combined heat and power systems.

RCL 583. Advanced Photovoltaics. 3 Hours
This theoretical course will cover science and applications of photovoltaics, with special emphasis on inorganic and organic semiconductors, ferroelectrics, chalcopyrites, metamaterials, and quantum structures. Prerequisite(s): ECE 506 or permission of instructor.

RCL 590. Special Problems in Renewable & Clean Energy. 1-6 Hours
Special problems in a designated area of energy systems arranged and approved by the student's faculty advisor and the departmental chair.

RCL 595. Renewable & Clean Energy Project. 0-3 Hours
Student participation in an energy related design or development project under the direction of a project advisor. The student must show satisfactory progress as determined by the project advisor and must present a written report at the conclusion of the project.

RCL 599. Renewable & Clean Energy Thesis. 1-6 Hours
Original research in energy systems which makes a definite contribution to technical knowledge. Results must be of sufficient importance to merit publication.