

**Graduate Handbook
Energy Science and Engineering Program**

**Bredesen Center for Interdisciplinary Research and Graduate Education
The University of Tennessee, Knoxville**

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Bredesen Center for Interdisciplinary Research and Graduate Education

An interdisciplinary doctoral degree in Energy Science and Engineering (ESE) has been developed at the University of Tennessee in order to educate students in energy-related fields that are of increasing importance to the state and the country. The ESE Faculty, based both at the University of Tennessee, Knoxville and Oak Ridge National Laboratory, provide research opportunities in various fields relating to the scientific and engineering challenges in energy supply and usage, including impacts on the environment and climate. The curriculum includes graduate courses specifically designed for the ESE program, but also draws on the graduate offerings of other departments and occasionally other universities to provide a broad interdisciplinary foundation for the ESE students. This program was initiated by Governor Phil Bredesen and funded by the State Legislature of Tennessee in 2010. This degree program is administered by the Bredesen Center for Interdisciplinary Research and Graduate Education, which has been established by the University of Tennessee, Knoxville and the Oak Ridge National Laboratory.

Lee Riedinger
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Introduction

The Bredesen Center for Interdisciplinary Research and Graduate Education has developed and offers one of the country's first interdisciplinary PhD programs for a degree in Energy Science and Engineering. The Bredesen Center expands the graduate research campus of the University of Tennessee, Knoxville (UTK) to include Oak Ridge National Laboratory (ORNL), greatly increasing research opportunities by combining the educational resources of a comprehensive research university and the research capabilities of a major national laboratory. This teaming arrangement provides expanded opportunities for graduate students in energy-related sciences and engineering, fostering interdisciplinary research, large-scale problem-oriented research projects, innovation and entrepreneurship. The ESE PhD offers coursework that serves two purposes: a broadening education in the issues of energy generation and use from many aspects and a deep dive into issues of energy in a given area of research. The students work on doctoral research in areas relating to energy in interdisciplinary teams of scientists and engineers working at UTK and ORNL.

The Bredesen Center offers graduate students opportunities to engage in interdisciplinary research while preserving the rigor and depth of a traditional PhD program. In addition, the ESE graduate curriculum is structured to include educational broadening elements that allow for supplemental studies in entrepreneurship, policy, or other energy-related fields. Entrepreneurial aspects of the program include partnership opportunities with the UTK College of Business Administration in developing and implementing business plans to accelerate the deployment of new technologies, in addition to the opportunity to learn from experienced science and engineering entrepreneurs at ORNL. Additionally, the Bredesen Center has developed opportunities for training in policymaking from UTK faculty and ORNL staff with experience in this area. The Bredesen Center is transformational in engaging graduate students in interdisciplinary projects, large-scale problem-oriented research programs, and science-to-applications research opportunities, enabling scientific breakthroughs and innovative solutions to energy-related challenges.

Energy science and engineering is an emerging field of study that builds on the conventional disciplines of science and engineering but is focused on the challenges and issues relating to the development and use of various sources of energy. The issues of energy supply and use provide our country and the world with some of the grandest challenges that citizens and institutions face now and for coming decades. Enabling research and development of alternative energy resources is a necessary step toward ending global dependence on fossil fuels and providing renewable and sustainable sources of energy for the world. Electricity from nuclear power is a largely non-carbon based form of energy supply, but has been stalled for decades due to issues of safety, politics, and public acceptance. Electricity from solar or wind farms is increasing in volume, but is not close to being cost competitive and constant in output for mass adaptation. Long-term development of electricity from fusion reactors is proceeding but is still several decades away.

The Graduate Program

Admission Requirements

In order to be admitted to the PhD program in Energy Science and Engineering, student applicants must fulfill the general admission criteria for the Graduate School of the University of Tennessee, Knoxville. In addition, the student must have a Bachelor of Science degree in either engineering or a scientific field (physics, chemistry, biology, mathematics, computational science, etc.), or the equivalent. Students with other undergraduate degrees may also be admitted on a case-by-case basis by the Bredesen Center Graduate Coordinating Committee. Dependent on the student's background, additional coursework may be required to satisfy co- and prerequisites.

Diversity and Access

Graduate students are nationally recruited for this doctoral program in a large annual campaign led by Oak Ridge National Laboratory. Recruiters from ORNL and the Bredesen Center visit a number of top universities across the U.S. to promote the ESE doctoral program with potential UTK graduate students. Diversity is a strong consideration in this recruitment process. Students are expected to understand and respect the diversity and access policies of UTK and ORNL and to conduct themselves in a professional manner at all times during their time in the program.

Students are expected to complete an orientation session hosted by the Bredesen Center before starting coursework. Additionally, graduate students who will be working at ORNL will be provided with additional information during a separate ORNL orientation. International students must complete any additional paperwork and training required by UTK or ORNL before set deadlines.

Degree Requirements

This graduate program leads to the Doctor of Philosophy (PhD) degree in Energy Science and Engineering (ESE). A minimum of 72 hours is required beyond the bachelor's degree, exclusive of credit for a Master's degree, and completion of the core requirements, as outlined in the section on Course Requirements. Of this number, a minimum of 24 and up to 36 hours of 600 Doctoral Research and Dissertation and **six hours of 600-level coursework at UTK will be required, exclusive of Doctoral Research and Dissertation credit.** In addition to coursework, students must pass a qualifying exam, a comprehensive exam, and a final exam which includes the preparation and defense of a dissertation. The graduate work is performed under the supervision of an advisor/major professor and a graduate committee.

Major Professor (Advisor)

Each graduate student must have an advisor/major professor from the Bredesen Center faculty, who can be either an ORNL or UT-based employee. This professor advises the student about course selection, supervises the student's research, and facilitates communication within the degree program and/or student's major department, to other departments, and with the Graduate School relative to requirements. The Assistant Director may act as a temporary advisor during

the period in which the student is becoming acquainted with the institutions and determining the focus of research interests. Once the major professor is determined, the major professor and the student together select a doctoral committee. The student is expected to maintain close consultation with the major professor and other members of the graduate committee with regard to progress in the program.

Doctoral Committee

The doctoral committees must have at least four members, generally chaired by the major professor that directs the dissertation research of the graduate student. Two committee members must be UTK-based tenured or tenure-track faculty. One member must be outside the Bredesen Center, but of course the two listed above fill this requirement. The other two committee members must have official UTK status, and these two could be adjunct or joint faculty affiliated with the Bredesen Center as ORNL staff, or they could be faculty based in UTK departments. The chair of the doctoral committee must have faculty status in a UTK tenured or tenure-track position or as joint faculty in the Bredesen Center as an ORNL staff member or as a UTC or UTHSC member. An adjunct faculty member cannot serve as the chair of the committee. It is suggested that Bredesen Center graduate students have five members on the dissertation committee, to be sure that there is sufficient coverage of the guidelines described above. The doctoral committee should meet at least annually to ensure sufficient progress of the graduate student towards a PhD.

Admission to Candidacy

Admission to candidacy indicates that the student has demonstrated ability to do acceptable graduate work and that satisfactory progress has been made toward the degree. This action usually connotes that all prerequisites to admission have been completed and a program of study has been approved.

A student may be admitted to candidacy for the doctoral degree after passing the comprehensive examination and maintaining at least a B average in all graduate coursework. Each student is responsible for filing the Admission to Candidacy form, which lists all graduate courses to be used for the degree, including courses taken at the University of Tennessee or at other institutions prior to admission to the doctoral program. The Admission to Candidacy form is signed by the doctoral committee.

Summer Registration

Graduate students must take a minimum of three credit hours in the summer, assuming they are engaged in research and/or courses at UT or ORNL. Before passing the qualifying exam, the student should register for ESE 502 – Registration for Use of Facilities to account for research hours. After passing the qualifying exam a student may enroll in ESE 600 – Doctoral Dissertation Research.

Doctoral Dissertation Research Credit (ESE 600)

After passing the qualifying exam, students should enroll in ESE 600 - Doctoral Dissertation Research to register their research hours. Once a student begins taking ESE 600 credit, they must take a minimum of three hours every semester thereafter continuously. Students should begin taking ESE 600 at least in the second summer, assuming the successful completion of the qualifying exam during the academic year.

Graduate Student Examinations

This section provides a description of the graduate student examination requirements for the PhD degree program. Three examinations are required as part of the doctoral program: qualifying examination, comprehensive examination, and defense of dissertation examination.

Qualifying Exam

A student must pass the qualifying examination to proceed in the PhD program. The qualifying examination is developed, administered, and graded by the Bredesen Center faculty (or designated subset of the faculty) of the PhD program under the coordination of the Bredesen Center Director. This examination must be taken no later than the end of the first year of ESE graduate studies. Given the research intensive focus of the Energy Science and Engineering doctoral program, it is expected that graduates of this program will possess the skills required to investigate and conduct research on a variety of problems. The qualifying exam will test these skills by challenging students to prepare a professional quality research proposal to address current important questions in energy science and engineering.

Late in the spring semester the ESE faculty will present the first-year students a set of problems relating to various topics of energy science and engineering. Each student must select one of these problems and construct a research proposal to thoroughly investigate the problem. The proposal should include an introduction, a background of the problem, the significance of the proposed study, the methodology that would be used to investigate the problem, and references to back up any claims. At the time problems are made available for selection, a due date for the completed written proposal will be announced. The student must also schedule an oral defense of their proposal to the qualifier committee.

Once the committee has made its final decision about the result of the examination, the committee must inform the student and the director of the Bredesen Center. In case of failure, the candidate may appeal to retake the examination through the Bredesen Center Graduate Education Committee within 30 days of notification of the result. If the appeal is granted, the student must retake the examination at the next offering. The result of the second examination is final. The successful completion of the qualifying examination grants students permission to engage in ESE 600 dissertation research.

Comprehensive Examination

The Comprehensive Examination should be taken at the end of a student's second year or later. The timing should be late enough in a student's academic program to permit most of his/her graduate course work to be covered on the examination, and early enough to permit modification of the student's program based on the results of the exam.

Two requirements must be satisfied before a student takes the Comprehensive Examination:

1. A written Dissertation Proposal, approved by the major professor, must be submitted to each member of the student's Doctoral Committee two weeks prior to the examination.
2. Each member of the student's Doctoral Committee must agree that the student is ready to take the Comprehensive Exam. The committee members will communicate to the major professor when they are satisfied that the student is ready to take the Comprehensive Exam.

The Comprehensive Examination will consist of the student constructing and defending his or her dissertation research proposal to the committee in a format deemed acceptable by the student's Doctoral Committee. Typically, an oral defense is sufficient for this examination, although a written component may be administered at the discretion of the Doctoral Committee.

Once the Comprehensive Examination is passed, the student should file for and be admitted to candidacy. At the discretion of the Doctoral Committee, supplemental reexaminations for the Comprehensive Examination and/or proposed dissertation research may be required. In case of failure, the candidate may not apply for reexamination until the following semester. The result of the second examination is final.

Defense of Dissertation Examination

A doctoral candidate must pass an oral examination on the dissertation. The dissertation, in the form approved by the major professor, must be distributed to the committee at least two weeks before the examination. The examination must be scheduled with the Graduate School and must be conducted in university-approved facilities. The examination is announced publicly and is open to all students and faculty members. The defense of dissertation will be administered by all members of the doctoral committee after completion of the dissertation and all course requirements. The major professor must submit the results of the defense by the dissertation deadline. All deadlines relative to the dissertation defense and graduation are posted on the Graduate School's website and are updated each semester.

Course Requirements

A minimum of 72 hours is required for the ESE doctoral program, and of this total a minimum of 36 hours of coursework is required beyond the BS degree. **36 hours of required coursework must be completed at a minimum for a student with a Bachelor's degree, including the Core Curriculum, a Knowledge Breadth Curriculum, a Knowledge Specialization Curriculum, and Seminar Series, as summarized below.**

A student with a Master's degree must complete 24 credit hours of coursework, including the Core Curriculum, a Knowledge Breadth Curriculum, a Knowledge Specialization Curriculum, and Seminar Series, as summarized below.

All students must complete a minimum of six hours of 600-level coursework, exclusive of Doctoral Research and Dissertation credit.

Students must maintain full-time status during the Fall and Spring semesters each year, and be engaged in at least three credit hours of dissertation research in the Summer semester. Students are encouraged to engage in summer courses if appropriate. **Each student is required to submit their proposed schedule of courses to the Academic Coordinator, the Academic Advisor, and their major professor before classes begin each semester.** Students that do not have a major professor should consult with the Academic Coordinator of the program in order to construct a course schedule that will sufficiently cover the subject matter related to the student's desired area of research.

A student may begin credited doctoral dissertation research - ESE 600 - after successfully completing the qualifying examination. Students who are deemed qualified by the director of the program may begin taking ESE 600 in the same semester as their qualifying examination. After beginning ESE 600, the student must continue to enroll in ESE 600 for a minimum of three hours every semester until the completion of their degree. A total of 36 credit hours of ESE 600 is required in order to graduate for a student with a Bachelor's degree. A total of 24 credit hours of ESE 600 is required in order to graduate for a student with a Master's degree.

Core Curriculum (6 credits)

ESE 511 and ESE 512 - Introduction to Energy Science and Technology. Topics include: energy basics; history of energy and society; current and future supply and demand; political and environmental aspects of energy production; energy technologies (fossil fuels, biomass, nuclear fission, nuclear fusion, solar, wind, geothermal); energy conversion, storage, transportation, and distribution; energy efficiency; and innovation.

Knowledge Breadth Curriculum (6 credits)

The Knowledge Breadth requirement includes six hours of coursework selected from the following areas:

1. Political, social, legal, ethical, and security issues related to energy
2. Entrepreneurship, leadership, and management

Other courses are eligible for consideration of the knowledge breadth requirement and all selections should be approved by the Academic Coordinator in advance of registration for the course.

Knowledge Specialization Curriculum (15 credits)

The Knowledge Specialization Curriculum is a deep dive into an area of science or engineering closely related to energy. In consultation with the advisor/major professor, each student must

submit a proposed course of study that includes at least 15 hours of approved courses. The Bredesen Center Academic Coordinator reviews and approves proposed courses of study. The course of study for each student must include at least nine credit hours of graduate-level fundamental courses and six hours of 600-level advanced courses.

A proposed course of study should focus on one of the following Bredesen Center themes:

1. Nuclear energy
2. Bioenergy and biofuels
3. Renewable energy
4. Energy Materials
5. Energy conversion and storage
6. Distributed energy and grid management
7. Environmental and climate sciences related to energy
8. Transportation Sciences
9. Energy Geography
10. Cross-Cutting Energy Sciences

Seminar Series (3 credits)

The ESE 599 seminar series will provide topical seminars related to Bredesen Center research themes or knowledge breadth areas. ESE will be offered each fall and spring semester and students must attend at least three semesters of seminar.

Approved Courses

Due to the interdisciplinary nature of this program, The Bredesen Center does not publish a list of pre-approved courses for the specialization or knowledge breadth requirements. Students should consult with their research mentor the appropriate coursework for their particular academic and research goals. Following these discussions students should provide the Academic Coordinator and Academic Advisor a copy of their plan each semester for progress and approval. The Bredesen Center Academic Advisor can also assist in locating courses to satisfy the Graduate School requirements.

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The Bredesen Center is named in honor of Governor Phil Bredesen, who served Tennessee from 2003 to 2011, in recognition of his leadership in education and economic development for the state. In addition his commitment to the Bredesen Center, Governor Bredesen's vision for capitalizing on the great potential of the UT-ORNL partnership resulted in the UT-ORNL Governor's Chairs program, the UT Biofuels Initiative, the Volunteer State Solar Initiative, and the UT-ORNL Joint Institutes for Computational Sciences, Biological Sciences, and Neutron Sciences.