PhD Training Program in Sustainable Energy Recovery from the Earth
-- Educational Innovation at the Intersection of Geosciences and Engineering
Guiding Philosophy of Cornell’s Earth-Energy PhD Program

Providing affordable energy to meet the demands of both developed and developing nations without further damaging the natural environment and the Earth’s climate system, is a Grand Challenge for the 21st century. Our quality of life and the stability of the world’s nations ultimately depend on having accessible energy resources and an equitable and sustainable energy supply and distribution system.

Achievement of these goals requires the participation, ingenuity, and hard work of people with a range of specialized backgrounds, working collaboratively and thinking globally.

New Technology Needs

- to exploit a range of subsurface energy sources (geothermal as well as fossil fuel) in an environmentally sustainable manner
- to use Earth’s subsurface to mitigate the energy waste products (e.g., CO₂ sequestration).

Future Workforce Needs

A new generation of scientists and engineers, able to work across the engineering-geosciences fields, and to appreciate, anticipate, and communicate about risks and economic balances of importance to communities.
Numerous challenges exist in this system, for which new research is vital.
Student Funding Alternatives

• U.S. citizens and permanent residents may apply to be NSF-IGERT Fellows, which would provide a 1 to 2 year fellowship, to be followed by GRA support arranged by an individual faculty member*

• Students are welcome to participate who hold fellowships from industry or another agency

• International students are welcome who hold fellowships from their home country or industry

* Off-campus parts of the program and laboratory use will entail added fees, for which the student’s sponsor must be responsible
Multidisciplinary Leadership of an NSF-sponsored IGERT
“Earth-Energy Integrated Graduate Research and Education Training Program”

Jefferson W. Tester – Principal Investigator
Department of Chemical and Biomolecular Engineering &
Director of Cornell’s Energy Institute
Core professor of Sustainable Energy Systems

Leadership Team

Teresa Jordan
Earth & Atmospheric Sciences

Jery Stedinger
Civil & Environmental Engineering

Donald Koch
Chemical & Biomolecular Engineering
A Multidisciplinary Faculty Team for the Earth-Energy Graduate Program
Faculty Participants & Fields

Geoff Abers, Earth and Atmospheric Sciences
Richard Allmendinger, Earth and Atmospheric Sciences
Lars Angenent, Biological and Environmental Engineering
Shefford Baker, Materials Science and Engineering
Larry Brown, Earth and Atmospheric Sciences
Lawrence Cathles, Earth and Atmospheric Sciences
Paulette Clancy, Chemical and Biomolecular Engineering
Ricardo Daziano, Civil and Environmental Engineering
Louis Derry, Earth and Atmospheric Sciences
Park Doing, Bovay Program in History and Ethics of Engineering
Christopher Earls, Civil and Environmental Engineering
Emmanuel Giannelis, Materials Science and Engineering
Andrew Hunter, Chemical and Biomolecular Engineering
Yong Joo, Chemical and Biomolecular Engineering
Kathleen Keranen, Earth and Atmospheric Sciences
Ronald Kline, Electrical and Computer Engineering Science and Technology Studies
Rowena Lohman, Earth and Atmospheric Sciences
Michal Moore, Energy Economics and Chemical and Systems Engineering
Perrine Pepiot, Mechanical and Aerospace Engineering
Matthew Pritchard, Earth and Atmospheric Sciences
Patrick Reed, Civil and Environmental Engineering
Susan Riha, Earth and Atmospheric Sciences
Christine Shoemaker, Civil and Environmental Engineering
Paul Steen, Chemical and Biomolecular Engineering
Abraham Stroock, Chemical and Biomolecular Engineering
John Thompson, Earth and Atmospheric Sciences
Derek Warner, Civil and Environmental Engineering
Alan Zehnder, Mechanical and Aerospace Engineering
Nature of the Educational Program: Cornell’s Earth-Energy Graduate Training Program

Interdisciplinary student participants
- brings together students seeking degrees in engineering and in geosciences
- designed to provide both communities with a common language

Teaching methods
- mini-courses, collaborative projects and exposure to real-world case studies lead to interdisciplinary training
- hands-on in the field teaching and practice of methodologies and interdisciplinary teamwork
- internships
- student teams collaborate on complex technical challenges
- case studies regarding the social impacts and ethical issues of energy solutions

Schedule for a student seeking the PhD
- Interdisciplinary Earth-Energy courses and project work during years 1-2
- Disciplinary Courses during years 1-3
- Focus on disciplinary research in years 3-5
### Educational Program Overview: Components of Earth Energy System Graduate Training Program

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<tr>
<th>IGERT Fellow Requirements</th>
<th>Modular courses</th>
<th>Field Project</th>
<th>Seminars</th>
<th>Internships</th>
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<tbody>
<tr>
<td>Nature of training activity</td>
<td>Technical background (see course list above); each credit ~4-week-duration</td>
<td>Off-campus team projects 1-2-week duration, following preparatory seminar in preceding semester; engineering-geoscience student team investigates solutions meeting economic, risk, environmental and social criteria; co-led by resident faculty members. Travel to (a) geological sites (e.g., revealing a pertinent “fossil” subsurface environment) and (b) a geoengineering site (i.e., geothermal production field; oil shale extraction facility; CO₂ sequestration test field).</td>
<td>Discussions with professional earth scientists and engineers, economists, environmentalists, ethicists, sociologists, etc., Follow-up seminar to develop design report and presentations.</td>
<td>Internship with energy–related non-academic organization (i.e., energy industry, government lab, NGO, etc.).</td>
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<tr>
<td>Fellow Requirement</td>
<td>5 or 6 required, depending on advice of each student’s faculty research committee; additional modules strongly recommended</td>
<td>Taken at least once by all Fellows. Participation requires payment of expenses for each student (student should discuss with their advisor the source of funds).</td>
<td>All Earth Energy program students for at least two semesters; open to other students by permission.</td>
<td>Strongly encouraged at least once during PhD program (funded by host agency or company)</td>
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<tr>
<td>Taken When?</td>
<td>At least 2 in first year and at least 2 by end of second year</td>
<td>January break and/or summer session following first or second year; preparatory seminar during preceding semester and wrap-up during following semester</td>
<td>Weekly during semesters</td>
<td>Summer or semester-long; timing flexible</td>
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# Course Topics: Cornell’s Earth-Energy Graduate Training Program

<table>
<thead>
<tr>
<th>Course Title</th>
<th>Core concepts</th>
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<tr>
<td><strong>Analysis of Sustainable Energy Systems</strong>  core course (3 credits)</td>
<td>Fundamentals of energy recovery and conversion; economics and finance; life cycle analysis: cradle-to-cradle concepts</td>
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<tr>
<td><strong>Earth System Behavior and Resources</strong>  core course (1 credit)</td>
<td>Biogeochemical cycles; climate as coupled atmosphere-ocean-solid earth phenomena; natural change and anthropogenic change; accumulation and maturation of organic matter</td>
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<tr>
<td><strong>Earth Energy Science and Engineering</strong>  core course (3 credits)</td>
<td>Compositional and mechanical rock properties; natural fluids and flows; subsurface detection; transport processes; interplay of pore and reservoir-scale reactive transport processes</td>
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<tr>
<td><strong>Geothermal Energy</strong>  case study module (1 credit)</td>
<td>Geological setting; enhanced geothermal system design</td>
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<tr>
<td><strong>Geological Carbon Sequestration</strong>  case study module (1 credit)</td>
<td>Carbon cycle and chemistry; two-phase fluid flow and capillary sealing; reservoir and seal rock systems; carbon-capture; risks and uncertainties; case studies</td>
</tr>
<tr>
<td><strong>Unconventional Natural Gas Development from Shale Formation</strong>  case study module (1 credit)</td>
<td>Resources and reserves; chemical and physical properties; drilling technology and impacts; hydraulic fracturing; infrastructure; water use and waste production; seismic risk; fugitive methane; economic and social impacts</td>
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<tr>
<td><strong>Risk and Uncertainty</strong>  module (1 credit)</td>
<td>Quantitative methods for risk and uncertainty assessment and management in energy and the environment</td>
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<tr>
<td><strong>Ethical, Social, and Political Issues in Energy System Research, Design, and Use</strong>  case study module (1 credit)</td>
<td>The historical context of the energy system; Social issues in sustainability; The concept of risk from a social perspective; Social and cultural issues in energy use; The relation between research and system design; International relations.</td>
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Other 1-credit energy modules that are not directly focused on subsurface energy technology include

- Solar Energy
- Wind Energy
- Transportation Systems
- Bioenergy and Biofuels
Make a Difference in Shaping a Sustainable Future for Energy, Environment, and Society:

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