SEF 534 Engineering Solutions to the Challenges of Energy and Global Climate Change

Stevens Institute of Technology

School: **Engineering and Science**

Course Title: **Engineering Solutions to the Challenges of Energy and Global Climate Change**

Program(s): Science & Engineering Foundations for Education (SEFE) – Interdisciplinary

Course #: SEF 534

Catalog Description:

Building on the science concepts developed in the prior courses in the SEFE sequence, this capstone course will examine the science principles supporting the engineering solutions being pursued for issues related to energy production/consumption and global change. As difficult as some of the challenges presented by these problems are, they will also be the driver of much of technological innovation in the 21st Century. Using a case study approach we will discuss from a systems perspective the energy science and engineering that is the basis for approaches being implemented to move to a more sustainable world, including the development of grid-scale solar power and wind power as well as engineering solutions to reduce the effects of global change. Content knowledge will be linked with pedagogical content knowledge and discussion of how the teachers will be able to locate, implement, and design age-appropriate materials based on science and engineering concepts for use in their own classrooms.

Course Objectives

SEFE534 is a capstone course for the Science & Engineering Foundations for Education Graduate Certificate Program and focuses on the science principles supporting the systems-level engineering solutions being pursued in the context of the national and global energy crisis. This knowledge will enable teachers to be able to utilize pre-existing science curricular materials, as well as design and or modify new materials, in their own classrooms. In this way, the teachers will be prepared, from both the perspective of content knowledge as well as pedagogical content knowledge, to provide a much richer science and engineering perspective within their science classrooms for the benefit of their students.

List of Course Outcomes:

The following Course Outcomes are based on the *Understanding By Design* framework that was utilized in the development of this course.

Enduring Understandings: After SEF 534 participants will understand:

1. The nature of engineering as a discipline and its relationship to the sciences and mathematics.

2. The engineering design process is a systematic approach that utilizes scientific knowledge to solve problems.

3. Solutions to the world's global energy challenge will require a systems-based view utilizing a diverse portfolio of alternative energy sources (sun, wind and water) and related sciences and technologies (e.g. photovoltaic, wind turbine, fuel cells).

4. Solutions to the nation's and world's energy challenge will require multi- and interdisciplinary efforts of scientists and engineers working together.

5. Energy demand of a community or a nation can be calculated and predicted. Engineers and scientists work together to develop strategies to meet the energy demands of the future.

6. Global change is influenced by natural and anthropogenic sources such as sun spots and the greenhouse effect.

7. In addition to scientific, engineering and technical issues, other factors such as political, economic, social, and safety factors must be factored into proposed solutions to the nation's and world's energy challenge.

Essential Questions: After SEF 534 participants will keep considering:

1. What were the engineering design considerations and constraints that went into the final design of the artifact/product?

2. What are ways in which engineers utilize, or could utilize, various scientific principles in the development of a new product or process?

3. For a particular application, what are the major advantages and disadvantages of a given alternative energy approach?

4. From a systems perspective, how does one address and balance the scientific and engineering issues/concerns of all stakeholders within a design scenario?

5. How are scientists/engineers today seeking to develop renewable/sustainable energies and solutions to global climate change?

Acquisition of Knowledge: After SEF 534 participants will know:

1. The major steps of the Engineering Design Process and the science inquiry approach.

2. Basic terminology and concepts related to Systems Engineering.

3. The key scientific principles upon which several methods of utility-scale alternative energy production are based.

4. The major positive and negative aspects regarding the implementation of several different alternative energy methods which may be used as future sources for utility scale energy.

5. Several examples of possible science lessons and activities that incorporate the items above and that could be adapted for use in their science classrooms.

Acquisition of Skills: After SEF 534 participants will be able to:

1. Describe how each phase/step of the Engineering Design Process and the Science Inquiry Approach may be applied to a given context or problem-based situation.

2. Apply the basic principles of Systems Engineering in the definition of the design of a large system (in the context of an alternative energy plant).

3. Identify the major challenges with respect to scaling a given alternative energy approach, and in particular being able to identify the major advantages and disadvantages of this alternative energy approach from the perspectives of various stakeholders.

4. Describe the basic science principles that support several different alternative energy approaches.

5. Apply 21st Century skills (creativity and innovation, communications and collaboration, critical thinking and problem solving) in the context of Engineering Design and Science Inquiry.

6. Design science lessons and activities that integrate science and engineering concepts, the Engineering Design Process, and science inquiry for use in their classroom

Prerequisites: Students must be part of CIESE's NSF funded PISA^2 program cohort for the initial offering of this course. Alternative prerequisites will be developed at the end of the PISA^2 program so that the courses may be offered for general use.

Cross-listing: N/A

Grading Percentages: HW (20%) Class work (0%)

Mid-term (0%) Mid-term Project (15%)

Final (25%) Final Project (25%)

Other: Online Discussion Forum (15%)

Textbook(s) or References

- Renewable Energy: Sustainable Energy Concepts for the Future, Edited by R. Wengenmayr and T. Buhrke, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2008. ISBN: 978-3-527-40804-7
- Energy in the 21st Century, by John R. Fanchi, World Scientific Publishing Co, Hackensack, NJ, 2011, ISBN: 9789814322041
- Energy: Technology and Directions for the Future, by John R. Fanchi, Elsevier Academic Press, Burlington, MA, 2004. ISBN: 9780122482915
- Energy and Society: An Introduction, Harold H. Schobert, Taylor & Francis, New York, 2002. ISBN: 9781560327677
- Principles of Sustainable Energy, Frank Kreith and Jan. F. Krieder, CRC Press, Boca Raton, FL, 2011. ISBN: 9781439814079

Mode of Delivery Class Online Modules

Other: Mixed (Class, Online)

Program/Department Ownership: Science & Engineering Foundations for Education Program – School of Engineering & Science

Department Point of Contact and Title: Professor Frank Fisher, Department of Mechanical Engineering

Date approved by individual school and/or department curriculum committee: 11/8/2011 by SEFE Program Committee

General: The course will be offered via blended delivery combining face-to-face classroom meetings and an online component in the order given below. The course will leverage existing materials (hands-on and curricular) developed by the Center for Innovation in Engineering and Science Education (CIESE) in the areas of both energy and systems, but at a deeper level of technical depth and rigor appropriate for a course of this nature and building upon and expanding the science topics covered in the earlier courses in the $PISA^2$ sequence. Examples of these sources include the PSE&G Energy Engineering Institute and the Systems and Global

Engineering Project (SAGE); the latter was developed by CIESE in conjunction with SSE faculty at Stevens. The order was designed to maximize the impact and utility of the face-to-face classroom meetings while fitting within a typical Stevens Spring semester schedule.

- A 2 hour 'pre-reading homework assignment' prior to the first class meeting
- A 3 hour face-to-face-meeting, F2F Session 1
- Over 3 week period: 6 hrs online discussion and activities and up to 9.5 hrs homework
- A 3 hour face-to-face-meeting, F2F Session 2
- Over 3 week period: 6 hrs online discussion and activities and up to 9.5 hrs homework
- A 3 hour face-to-face-meeting, F2F Session 3
- Over 3 week period: 6 hrs online discussion and activities and up to 9.5 hrs homework
- A 3 hour face-to-face-meeting, F2F Session 4
- Over 4 week period: 6 hrs online discussion and activities and up to 9.5 hrs homework, with the extra time allocated for Final Project
- A 3 hour face-to-face-meeting, F2F Session
- A 3 hour face-to-face-meeting for the Final Exam

	Topic(s)	Reading(s)	Class exercises (Optional)	HW
Before Day 1	Content pre-test to be administered at the school (PISA^2 data collection)	N/A	N/A	2 hours of pre-reading for first F2F Session: - Introduction to Engineering Design (EDP) - Introduction to Systems Engineering (SE)
F2F Session 1 (3 hours)	- The Engineering Design Process, Science Inquiry Approach and Systems Engineering Overview - Online resources for K12 science/engineering-related modules for grades 3-8	N/A	Discussion of examples of the application of engineering design, science inquiry and systems-level thinking as related to alternative energy science (Two common everyday items will be examined. For the first item the Instructor will lead a brainstorming session of how principles of systems and engineering design were manifest in the final consumer project; for the second item the Instructor will facilitate small group discussion amongst the class)	Additional problems where students will work in teams to identify elements of the EDP and elements of SE (hours counted below)
Online Session 1 (6 hours with 9.5 hrs HW)	- Science/Engineering Disciplines and their contributions to Alternative Energy - Introduction to Grid-scale Alternative Energy	- Selected textbook readings discussing the different engineering fields - Select, short pre-reading overview of the PSE&G and PV Energy Kits (hands-on exercise in next F2F session)	Moderated and facilitated online discussion forums of the readings	Identification and review of alterative energy-based science/engineering modules they have identified on the web, focusing on practicality of classroom integration
F2F Session 2 (3 hours)	- Summary and discussion of Online Session 1 work - Introduction to grid-scale photovoltaic energy - Introduction to grid-scale wind energy	N/A	PSE&G Wind Energy Kits (experimental testing of model wind energy kit as a function of several variables such as blade shape, air/fan speed, etc; discussion of how scales to larger length scales)	- selected problems related to science content from Courses 1 to 4 in the PISA2 sequence related to wind and PV energy (hours counted below)

Online Session 2 (6 hours with 9.5 hrs HW)	- Scaling results from Energy Kits to grid-scale level - Midterm Project	- Selected textbook readings related to grid-scale photovoltaic energy - Selected textbook readings related to grid-scale photovoltaic energy	Moderated and facilitated online discussion forums of the readings	- selected HW problems based on reading material - Midterm Reflection Paper - Midterm Project Proposal: Development of an Introduction to Engineering grade-appropriate module focusing on systems-levels
F2F Session 3 (3 hours)	- Introduction to the Hydrogen Economy - Midterm Project Proposal Presentations	N/A	- Quantitative discussion of select topics (science, engineering, systems) related to hydrogen as an energy source and its scaling (see DOE sources). A potential demonstration unit could be similar to a past project used in E231 (Design III) - Midterm Proposal Presentations (small groups of students present their midterm projects)	- selected HW problems based on wave energy
Online Session 3 (6 hours with 9.5 hrs HW)	Midterm Science/Engineering Project: Final Design, Critique, Implementation, and Evaluation, Redesign, and Reflection	N/A	Moderated and facilitated online discussion forums for each group project, including peer critique of other groups, implementation and evaluation, lessons learned and re-design, and reflection	- Field trip to PSE&G Power Plant or similar facility (PISA2 partner)
F2F Session 4 (3 hours)	- Introduction to Systems Tools & Engineering Economic Analysis (focusing on what is needed for the final project) - Final Project: Introduction and Initial brainstorming	N/A	This F2F session will be tailored to assisting students in starting their Final Projects. (Potential Final Project Scenario: An older energy plant is nearing decommission and as a member of the Community Board you are asked for quantitative input regarding the feasibility of different renewable energy sources being considered)	N/A

Online Session 4 (6 hours with 9.5 hrs HW)	This final online session is devoted to having the students work on their Final Projects. The online forums will be utilized here to facilitate communication and questions between the different groups and the course instructors.			
F2F Session 5 (3 hours)	Final Project Presentations		- Short presentation (Elevator Speech) and Poster Presentation of each group's Final Project - Students will be asked to peer-grade and comment on each group presentation	Reflection papers based on comments/feedback of their final project presentations
F2F Session 6 (3 hours)	- Discussion and Reflection on Course Learning - Final Exam			