Northeastern University College of Engineering

Department of Mechanical and Industrial Engineering

Boston, MA 02115

MEIE 4701/4702 Capstone Design 1 & 2

Instructor: Professor Yiannis Levendis; Professor Gregory Kowalski

Course Description: (Capstone Design 1) offers the first in a two-course sequence that culminates the student's education and experience with the design process. Students form teams and are assigned their design project and faculty adviser. Projects can be industrially, departmentally, or externally sponsored. Students are expected to communicate with their faculty adviser, course coordinator, and sponsor using the Internet, teleconferencing, and other electronic methods. Topics include project management, ethics, cost analysis, Internet and library research methods, and engineering codes and standards. Students prepare written reports and make oral presentations. Students are expected to complete a thorough state-of-the-art report on their problem and a problem statement with specifications and requirements.

(Capstone Design 2) Continues MEIE 4701. Students are expected to apply engineering principles acquired throughout their undergraduate academic and co-op experiences to the design of a system, component, or process. Each project includes the development and use of design methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, and detailed system descriptions. Projects include realistic constraints such as economic factors, safety, reliability, maintenance, aesthetics, ethics, and political and social impact. Students make oral presentations on their results in a series of design reviews. Students document their solutions using a written report that includes an executive summary. A working prototype or simulation, as appropriate, of their solution is required to complete the course.

Heliostat Sun and Tower Tracking Project

A heliostat is a moveable mirror used in concentrated solar power (CSP) applications, which use an array of mirrors to reflect sunlight into a receiver that heats a high temperature fluid. Existing CSP fields use an open-loop system, relying on astronomical data to focus the sunlight. However, if a heliostat's position were to change due to weather or environmental conditions, open-loop heliostats have no way to check if they are aiming the sunlight at the receiver. Therefore, this project is developing a closed-loop heliostat system for the National Renewable Energy Laboratory of United States Department of Energy to improve accuracy and efficiency of heliostats. The chosen solution consists of three primary units: a solar tracker that detects the location of the sun, a self-moving mirror that reflects the light to target, and a receiver that acts as a locating beacon for the mirror and a target for the reflected sunlight. The solar tracker's algorithm uses feedback from four lux sensors to find the azimuthal and zenith angles of the sun; it then sends those angles to the mirror, which uses those inputs to calculate the bisecting vector between the sunlight and the receiver to reflect the light at the target. After talking to NREL consultants, we realized that we needed comparable precision to current solutions, and to be fully closed-loop, our solution would have to detect the position of the receiver tower. To improve the precision a cap was added to the solar tracker, which blocked the sunlight unless the rays were normal to the lux sensors within 0.1°. Furthermore, limit switches were added, together with proximity sensors to both the mirror and tracker to decrease error accumulation over time using a homing sequence. Lastly, a beacon was added to the receiver, which the mirror can use to detect its position. At scale, with the use of such a design, if the mirrors are ideally positioned, then the power production of the plant could potentially double. However, even a small increase in the overall efficiency of the plant would result in millions more MWH produced per year, and it would enhance the economics of CSP plants.
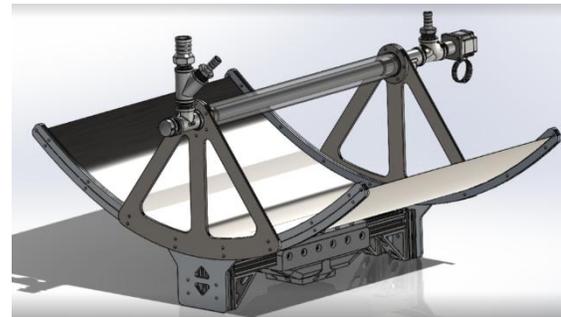
Deformable Heliostat Phase II

Central Receiver Systems (CRS) use thousands of heliostats, or sun-tracking mirrors, to concentrate light onto a central tower to produce electricity. Current reports estimate CRS could see a 50% increase in overall efficiency simply from design and cost improvements of its heliostats. To achieve this goal, and help further the transition to renewable energy, we designed a novel heliostat that uses deformation of the mirror surface as an alternative to traditional sun-tracking methods. The DEFLEX (Deformable Focusing Light Experimental) Heliostat features an acrylic mirror that can be manually deformed at each corner. This deformation creates off-axis parabolic shapes which can shift the focal point of its reflection as the sun moves throughout the day. The curvature of the mirror also increases concentration of light as opposed to the standard flat heliostat. Through iteration, simulation, and testing, we have determined that a deformable heliostat can complement traditional methods to increase efficiency and concentration of a CRS plant.

Solar Pyrolyzer

Rising global temperatures have caused an increase in forest fires devastating neighborhoods, depleting natural resources, and harming wildlife. These fires can cause such damage due to excess biomass found on forest floors. Therefore, this project aims to mitigate the harm caused by these fires by incentivizing the cleanup of pine needles from forest floors by building a device – a solar pyrolyzer - to convert this biomass to a more useful resource. The project aims to design, build, and test a uniaxial rotating parabolic solar thermal trough to pyrolyze dried pine needles into biofuel products including biochar, bio-oil and biogas. A parabolic trough collector will reflect sunlight onto a focal tube facilitating a seamless feeding process and a moderate temperature pyrolysis process that will yield the highest ratio of biochar relative to other products. The system will consist of the parabolic trough collector (PTC) system and its mechanical fixtures, a continuous feeder mechanism to move the pine needles through the pyrolysis chamber, and a collection device for the bio-oil and biochar produced. Sun-tracking software will be programmed based on historical solar position data which autonomously rotates the trough to follow the relevant motion of the sun throughout the day. This will allow for the greatest conversion of solar energy to the heat needed for the thermal pyrolysis of the pine needles at the focal tube of the reflective parabolic trough of the pyrolyzer. Our student Alexandra Vergara-Anglim attended the **2025 AAAS Conference in Boston** and took part in a poster competition where she presented this project.