Course Description:

The logistics and cost of moving and storing energy vary greatly by energy form and geographic region. This mini begins with a global look at resources and the sources, movements, processing and storage of fossil and nuclear fuels. Once fuels have been delivered and converted to heat or electricity, the issues of moving and storage re-emerge. Efficient use of renewable electric power resources is considered, with emphasis on distributed resources and managing variability and intermittency. The technical and economic aspects of electric power transmission, distribution and storage are also evaluated. Management, regulation and operation of the grid are evaluated, including various Smart Grid and Micro Grid initiatives and technologies in the US and worldwide.

Number of Units: 6
Course material: Lecture notes and slides

Text Book: Essentials of Energy Technology: Sources, Transport, Storage, Conservation

Pre-requisites: Students enrolled in EST&P master’s program; others with engineering BS degree and the permission of the instructor.

Communications: CANVAS postings and email announcements will be the primary communications medium. To access the course canvas from an Andrew Machine, go to the login page at: https://cmu.instructure.com/. You are responsible to read your Andrew account email announcements and to check the course CANVAS site.

Learning Objectives: Students will gain a fundamental understanding of technologies, costs, and benefits involving various alternatives for energy transport and storage. These include mobile energy carriers (hydrogen, electricity, natural gas) and traditional fossil fuel (coal, petroleum) and nuclear fuel delivery. Students will be able to:

(i) Discuss the underlying technology considerations underpinning energy transport and storage;

(ii) Perform technical / economic analysis of the transport and storage of fossil and nuclear fuels for energy generation;

(iii) Identify the various components of electric power transmission and distribution systems;

(iv) Perform tradeoff analysis comparing long distance energy transmission options (e.g. High Voltage AC vs. High Voltage DC transmission, natural gas pipelines, shipping and rail, etc.);

(v) Identify and perform trade-off analysis for various electric storage technologies (e.g. battery, pumped hydro, compressed air, etc.) for different applications (e.g. frequency regulation, day / night load shifting, upgrade deferral, smoothing intermittency);

(vi) Explain fundamentals of Smart Grid technology in electric power transmission and distribution as well as the benefits and challenges of distributed energy resources and microgrid technology;

Evaluation: Homework Assignments 30%
Class Participation 10%
Comprehensive Final 30%
Project Poster Presentation 15% (individual evaluation)
Project Poster 15% (group evaluations)

Grade Scale: A: 90-100  B: 80-89  C: 70-79  D: 60-69  F: < 60
COURSE POLICIES:

- Homework: All homework assignments will be submitted through CANVAS. Each person will be allowed two late days for the semester. Late assignments beyond the two late days will not be accepted. For every late day, you will lose 5% of your grade. NOTE: Only neatly written problems will be graded.

- Grading: Although we will try our best to grade fairly, everyone makes mistakes. If you believe that we have made a mistake in grading your homework or test, you have one week from the date that the graded item is returned to request a re-grade. Of course, we may find that we missed some mistakes that you made, so your grade may go up or down on re-grading.

Projects Assignment: Team-based project to evaluate regional energy Transport & Storage infrastructure & status for an assigned region. Make projections of future regional T&S needs, challenges and shortfalls (~25 years). Evaluate options and make recommendations for optimal new and modified energy transport & storage infrastructure and practices needed for the assigned region. Perform quantitative analysis using the HOMER package in system representative of assigned region to justify recommendations.

Course Topics

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<thead>
<tr>
<th>Date</th>
<th>No.</th>
<th>Topic</th>
<th>Assignment</th>
<th>Participation</th>
<th>Instructor</th>
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<tbody>
<tr>
<td>Tuesday, 10/27</td>
<td>1</td>
<td>Motivation and Overview</td>
<td></td>
<td>In-person + remote</td>
<td>Dr. Mohammadi</td>
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<tr>
<td>Thursday, 10/29</td>
<td>2</td>
<td>Centralized vs. Distributed Energy Systems</td>
<td>HW #1 assigned</td>
<td>In-person + remote</td>
<td>Dr. Mohammadi Anand Yadav</td>
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<td>HOMER Introduction</td>
<td>Energy news-group 1</td>
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<td>Tuesday, 11/3</td>
<td>3</td>
<td>Fundamentals of Mass, Heat, and Electrical Transport</td>
<td>Project team + region assignments</td>
<td>In-person + remote</td>
<td>Dr. Babaei</td>
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<td>of Energy Carriers</td>
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<td>Thursday, 11/5</td>
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<td>Overview of Energy Storage Technologies</td>
<td>Energy news- group 2</td>
<td>In-person + remote</td>
<td>Dr. Mohammadi</td>
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<td>Energy news- group 3</td>
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<td>Tuesday, 11/10</td>
<td>5</td>
<td>Transport &amp; Storage of Coal, Natural Gas, and</td>
<td>HWK #1 due</td>
<td>In-person + remote</td>
<td>Dr. Mohammadi</td>
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<td>Petroleum Energy Sources</td>
<td>HWK #2 assigned</td>
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<td>Energy news- group 4</td>
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<td>Thursday, 11/12</td>
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<td>Guest Lecture: Transport &amp; Storage of Nuclear Energy</td>
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<td>In-person + remote</td>
<td>Rebecca Willmott</td>
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<td>Tuesday, 11/17</td>
<td>7</td>
<td>Optimization in energy systems- part 1</td>
<td>Energy news- group 5</td>
<td>In-person + remote</td>
<td>Dr. Mohammadi</td>
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<td>Thursday, 11/19</td>
<td>8</td>
<td>Optimization in energy systems- part 2</td>
<td>HWK #2 due</td>
<td>In-person + remote</td>
<td>Dr. Mohammadi</td>
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<td>HWK #3 assigned</td>
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<td>Energy news- group 6</td>
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<td>Tuesday, 11/24</td>
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<td>Class presentation</td>
<td>Project preliminary design review submission</td>
<td>In-person + remote</td>
<td>Dr. Mohammadi</td>
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<td>Thursday, 11/26</td>
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<td>Thanksgiving Holiday: No Classes</td>
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<td>Tuesday, 12/1</td>
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<td>Guest Lecture: How is Covid-19 affecting the electric</td>
<td>Energy news- group 7</td>
<td>remote</td>
<td>Dr. Kyri Baker</td>
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<td>power grid?</td>
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<td>Thursday, 12/3</td>
<td>11</td>
<td>Emerging Topics in Energy System</td>
<td>Energy news-group 8</td>
<td>remote</td>
<td>Dr. Mohammadi</td>
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<td>HWK #3 due</td>
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<td>Tuesday, 12/8</td>
<td>12</td>
<td>Guest Lecture: Energy systems in developing countries</td>
<td>All poster pptx files</td>
<td>remote</td>
<td>Dr. Barry Rawn</td>
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<td>Thursday, 12/10</td>
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<td>Final Poster Session for Project Teams</td>
<td>due Wed.12/9 by 9am</td>
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<td>Dr. Mohammadi &amp; other</td>
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<td>TBD</td>
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<td>Course Final Exam</td>
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Hybrid/Remote attendance:

This class will be taught in hybrid mode, meaning it allows in-person (rotation)-plus-remote (IRR) participation. Active participation in class and outside of the class through the Canvas chat is an essential component of the course and your grade. However, please be mindful of the following considerations:

- **If the class needs to go fully remote, you will receive an email from me (the instructor) and an announcement will be published on our course website on Canvas. During the semester, we will use the same zoom link available on Canvas (in the first module of the landing page) and the beginning of the course syllabus.**

- **At any point during the semester, you may choose to participate in the class remotely. If you decide to switch to remote for one or more classes, please try to let me know by email jmohamma@andrew.cmu.edu at least 24 hours in advance so I can prepare the breakout rooms and in-class sessions appropriately. In addition, if you are able, let me know the expected length of your remote engagement (e.g., number of classes or for an extended period of time).**

- **This semester involves regular use of technology during class – both for in-person and remote students. Research has shown that divided attention is detrimental to learning, so I encourage you to close any windows not directly related to what we are doing while you are in class. Please turn off your phone notifications and limit other likely sources of technology disruption, so you can fully engage with the material, each other, and me. This will create a better learning environment for everyone.**

Use of Zoom in the class (including use of video)

In our class, we will be using Zoom for synchronous (same time) sessions. The links are available on Canvas and this document. Please make sure that your Internet connection and equipment are set up to use Zoom and able to share audio and video during class meetings. (See this page from Computing Resources for information on the technology you are likely to need.) Let me know if there is a gap in your technology set-up as soon as possible, and we can see about finding solutions.

Sharing video: In this course, being able to see one another helps to facilitate a better learning environment and promote more engaging discussions. Therefore, our default will be to expect students to have their cameras on during lectures and discussions. However, I also completely understand there may be reasons students would not want to have their cameras on. If you have any concerns about sharing your video, please email me as soon as possible and we can discuss possible adjustments. Note: You may use a background image in your video if you wish; just check in advance that this works with your device(s) and internet bandwidth.

- **During our class meetings, please keep your mic muted unless you are sharing with the class or your breakout group.**

- **If you have a question or want to answer a question, please use the chat or the “raise hand” feature (available when the participant list is pulled up). I [or the TA] will be monitoring these channels in order to call on students to contribute.**

All synchronous classes will be recorded via Zoom so that students in this course (and only students in this course) can watch or re-watch past class sessions. Please note that breakout rooms will not be recorded. I will make the recordings available on Canvas as soon as possible after each class session (usually within 3 hours of the class meeting). Recordings will live in our Canvas website. Please note that you are not allowed to share these recordings. This is to protect your FERPA rights and those of your fellow students.
Student Support and well-being:

If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at access@andrew.cmu.edu.

This semester is unlike any other. We are all under a lot of stress and uncertainty at this time. Attending Zoom classes all day can take its toll on our mental health. Make sure to move regularly, eat well, and reach out to your support system or me jmohamma@andrew.cmu.edu if you need to. We can all benefit from support in times of stress, and this semester is no exception. Please refer to resources listed [here] on for more information.

Expectations for Coming to Class:

In order to attend class in person, I expect that you will abide by all behaviors indicated in A Tartan’s Responsibility, including any timely updates based on the current conditions. In terms of specific expectations for in-person students, this includes:

- entering the classroom via the designated ingress route with appropriate physical distancing,
- wearing a facial covering throughout class,
- sitting in the seats with appropriate spacing (and not moving furniture),
- using the sanitizing wipes available in the classroom to wipe surfaces (e.g., your desk, tablet arm) upon entry and exit,
- exit the classroom at my direction, proceeding in a row-by-row fashion, following the designated egress route and maintaining proper distancing.

Facial coverings. If you do not wear a facial covering to class, I will ask you to put one on (and if you don’t have one with you, I will direct you to a distribution location on campus). If you do not comply, please remember that you will be subject to student conduct proceedings, up to and including removal from CMU. Accordingly, the instructor will be obliged to take other measures for the safety of the whole class.

CMU Academic Integrity Policy (http://www.cmu.edu/academic-integrity/index.html):

In the midst of self exploration, the high demands of a challenging academic environment can create situations where some students have difficulty exercising good judgment. Academic challenges can provide many opportunities for high standards to evolve if students actively reflect on these challenges and if the community supports discussions to aid in this process. It is the responsibility of the entire community to establish and maintain the integrity of our university.
This site is offered as a comprehensive and accessible resource compiling and organizing the multitude of information pertaining to academic integrity that is available from across the university. These pages include practical information concerning policies, protocols and best practices as well as articulations of the institutional values from which the policies and protocols grew. The Carnegie Mellon Code, while not formally an honor code, serves as the foundation of these values and frames the expectations of our community with regard to personal integrity.

*This policy applies, in all respects, to this course.*

**Diversity, Equity, and Inclusion Statement**

Every individual must be treated with respect. The ways we are diverse are many and are critical to excellence and an inclusive community. They include but are not limited to: race, color, national origin, sex, disability, age, sexual orientation, gender identity, religion, creed, ancestry, belief, veteran status, or genetic information. We at CMU, will work to promote diversity, equity and inclusion because it is just and necessary for innovation. Therefore, while we are imperfect, we will work inside and outside of our classrooms, to increase our commitment to build and sustain a community that embraces these values.

It is the responsibility of each of us to create a safer and more inclusive environment. Bias incidents, whether intentional or unintentional in their occurrence, contribute to creating an unwelcoming environment for individuals and groups at the university. If you experience or observe unfair or hostile treatment on the basis of identity, we encourage you to speak out for justice and support in the moment and and/or share your experience anonymously using the following resources:

Center for Student Diversity and Inclusion: csdi@andrew.cmu.edu, (412) 268-2150, www.cmu.edu/student-diversity

Report-It online anonymous reporting platform: www.reportit.net username: *tartans* password: *plaid*

All reports will be acknowledged, documented and a determination will be made regarding a course of action.” All experiences shared will be used to transform the campus climate.

**The Carnegie Mellon Code**

Students at Carnegie Mellon, because they are members of an academic community dedicated to the achievement of excellence, are expected to meet the highest standards of personal, ethical and moral conduct possible.

These standards require personal integrity, a commitment to honesty without compromise, as well as truth without equivocation and a willingness to place the good of the community above the good of the self. Obligations once undertaken must be met, commitments kept.
As members of the Carnegie Mellon community, individuals are expected to uphold the standards of the community in addition to holding others accountable for said standards. It is rare that the life of a student in an academic community can be so private that it will not affect the community as a whole or that the above standards do not apply.

The discovery, advancement and communication of knowledge are not possible without a commitment to these standards. Creativity cannot exist without acknowledgment of the creativity of others. New knowledge cannot be developed without credit for prior knowledge. Without the ability to trust that these principles will be observed, an academic community cannot exist.

The commitment of its faculty, staff and students to these standards contributes to the high respect in which the Carnegie Mellon degree is held. Students must not destroy that respect by their failure to meet these standards. Students who cannot meet them should voluntarily withdraw from the university.

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Cheating

(http://www.cmu.edu/academic-integrity/cheating/index.html) states the following:

According to the University Policy on Academic Integrity, cheating "occurs when a student avails her/himself of an unfair or disallowed advantage which includes but is not limited to:

- Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
- Use of an alternate, stand-in or proxy during an examination.
- Copying from the examination or work of another person or source.
- Submission or use of falsified data.
- Using false statements to obtain additional time or other accommodation.
- Falsification of academic credentials."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Plagiarism (http://www.cmu.edu/academic-integrity/plagiarism/index.html) states the following:

According to the University Policy on Academic Integrity, plagiarism "is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to: (i) Text, either written or spoken, quoted directly or paraphrased. (ii) Graphic elements (iii) Passages of music, existing either as sound or as notation. (iv) Mathematical proofs (v) Scientific data (vi) Concepts or material derived from the work, published or unpublished, of another person." This policy applies, in all respects, to this course.
Carnegie Mellon University's Policy on Unauthorized Assistance

(http://www.cmu.edu/academic-integrity/collaboration/index.html) states the following:

According to the University Policy on Academic Integrity, unauthorized assistance "refers to the use of sources of support that have not been specifically authorized in this policy statement or by the course instructor(s) in the completion of academic work to be graded. Such sources of support may include but are not limited to advice or help provided by another individual, published or unpublished written sources, and electronic sources. Examples of unauthorized assistance include but are not limited to:

- Collaboration on any assignment beyond the standards authorized by this policy statement and the course instructor(s).
- Submission of work completed or edited in whole or in part by another person.
- Supplying or communicating unauthorized information or materials, including graded work and answer keys from previous course offerings, in any way to another student.
- Use of unauthorized information or materials, including graded work and answer keys from previous course offerings.
- Use of unauthorized devices.
- Submission for credit of previously completed graded work in a second course without first obtaining permission from the instructor(s) of the second course. In the case of concurrent courses, permission to submit the same work for credit in two courses must be obtained from the instructors of both courses."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Research Misconduct

(http://www.cmu.edu/academic-integrity/research/index.html) states the following:

According to the University Policy for Handling Alleged Misconduct In Research, “Carnegie Mellon University is responsible for the integrity of research conducted at the university. As a community of scholars, in which truth and integrity are fundamental, the university must establish procedures for the investigation of allegations of misconduct of research with due care to protect the rights of those accused, those making the allegations, and the university. Furthermore, federal regulations require the university to have explicit procedures for addressing incidents in which there are allegations of misconduct in research.”

The policy goes on to note that “misconduct means:

- fabrication, falsification, plagiarism, or other serious deviation from accepted practices in proposing, carrying out, or reporting results from research;
- material failure to comply with Federal requirements for the protection of researchers, human subjects, or the public or for ensuring the welfare of laboratory animals; or
- failure to meet other material legal requirements governing research.”
“To be deemed misconduct for the purposes of this policy, a ‘material failure to comply with Federal requirements’ or a ‘failure to meet other material legal requirements’ must be intentional or grossly negligent.”

To become familiar with the expectations around the responsible conduct of research, please review the guidelines for Research Ethics published by the Office of Research Integrity and Compliance.

*This policy applies, in all respects, to this course.*

**Take care of yourself.** Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at [http://www.cmu.edu/counseling/](http://www.cmu.edu/counseling/). Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

If you have questions about this or your coursework, please let me know.