



MARYLAND APPLIED GRADUATE ENGINEERING

Advanced Audit, Modeling, and Management of Building Energy Systems (ENPM670)

Professor: Dr. Rakesh Radhakrishnan (Lead Instructor)
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Office Hours: Monday, Tuesday 2:30 – 4 PM (by Zoom), additional 3 hrs ad hoc, upon request

Professor: Dr. Michael Ohadi (Invited lectures/Supporting Instructor)
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Office Hours: ###

Term: Fall 2024

Credits: 03

Semester Dates: From August 26th – December 9th

Course Times and Location

Tuesdays 4:00 – 6:40 pm — JMP 2216

Canvas/ELMS: ###

Course Description

This course provides students with fundamentals and applications of energy audit, modeling, and management in building energy systems. It will begin with an overview of key definitions, units and the supply/demand fundamentals for the various energy sources and the challenges of decarbonization (across several sectors) will be addressed. The technologies used to provide various forms of energy (non-renewable and renewable) for use across various sectors will be presented along with methods for evaluating the economics of these options. This will be followed by a deeper dive on the drivers of energy demand in the buildings sector (residential, commercial, manufacturing). Energy audit procedures for electrical, lighting, mechanical, and HVAC systems will be covered, and the economics/life-cycle costing analysis will be included. Students will gain experience conducting energy audits through real-world project(s), different modeling tools (e.g. System Advisor Models) and data sources necessary to conduct core analyses across sectors will be covered.

Prerequisites

Students are expected to have prior knowledge of undergraduate basic thermodynamics and heat transfer. Knowledge of basic electrical systems and controls is desirable.

Learning Outcomes

After successfully completing this course, you will be able to:

- Describe the fundamentals of the US energy industry and decarbonization challenges across all major CO₂-producing industries.
- Provide insights on fuel and electricity markets, and the economics of the underlying technology options (non-renewable and renewable) used in those markets.
- Analyze the fundamentals of building energy consumption based on the underlying technologies that drive this consumption such as building envelopes, lighting, HVAC equipment, and controls.
- Conduct energy audits for residential and emerging mission-critical facilities (i.e., data centers)
- Analyze the energy management and decarbonization challenges for “hard to abate” sectors while describing technology options that could address those challenges in the future.

Course Materials

There is no required textbook for the course. However, recommended reference books and reports are given below. PowerPoint lecture notes will be provided and uploaded to the course website the evening before so students can review the lecture materials before our classroom time. There will be several additional useful links in the lecture notes to serve as additional learning material.

Recommended

Reference books:

1. Energy Audit of Building Systems: An Engineering Approach, Second Edition, by Moncef Krarti, CRC Press, 2010.
2. Guide to Energy Management 7 Ed. by Capehart, Barney L., Wayne C. Turner, and William J. Kennedy. CRC Press, Inc., 2010.
3. Understanding Today's Electricity Business Paperback, by Bob Shively, John Ferrare, 2010.
4. Understanding Today's Natural Gas Business Paperback by Bob Shively, John Ferrare, 2010.

Reports:

1. EIA Annual Energy Outlook 2023. <https://www.eia.gov/outlooks/aeo/>
2. Decarbonizing the U.S. Economy by 2050, National Blueprint for the Buildings Sector, 2024. <https://www.energy.gov/eere/articles/decarbonizing-us-economy-2050>
3. Industrial Decarbonization Roadmap DOE/EE-2635, 2022. <https://www.energy.gov/sites/default/files/2022-09/Industrial%20Decarbonization%20Roadmap.pdf>

Course Structure

This course includes both on-campus and online sections. To attend synchronously online, log into ELMS-Canvas at the time of the **Section 0101 class Wednesday at 7:00 pm** and select "Video Conference" from the left side menu. This will open a Zoom link to the live classroom.

For asynchronous online students, all lectures will be recorded and made available on ELMS-Canvas under "Panopto Recordings/Video Lectures" within 24 hours of the class time. Be sure to review the recorded lecture in a timely manner.

On-campus students come to class prepared to engage with the lecture and materials. Online students, be sure to log into Canvas regularly and participate in discussions and activities. Regardless of the section you are enrolled in, participation is expected.

Please note that F1 students enrolled in the on-campus section are required to attend in person. If you have a conflict on a particular day, please reach out to me in advance to discuss.

Communication Guidelines

Communicating with the Instructor

Questions by e-mail are welcome and will be responded to as quickly as possible, typically within 24 hours. Phone calls or web-based meetings can be scheduled as needed when requested in advance.

When constructing an email to me please put “ENPM 670 : Your Topic” in the subject line. This will draw my attention to your email and enable me to respond to you more quickly.

Additionally, please review [These tips for 'How to email a Professor'](#). By following these guidelines, you will be ensured to receive a timely and courteous response.

Finally, if you need to discuss issues not appropriate for the classroom and/or an email, we can arrange to talk by phone, over Zoom, or in person. Send me an email asking for a meeting and we can set something up.

Announcements

I will send IMPORTANT messages, announcements, and updates through ELMS-Canvas. To ensure you receive this information in a timely fashion, make sure your email and announcement notifications (including changes in assignments and/or due dates) are enabled in ELMS-Canvas ([How to change notification settings in CANVAS](#)).

Log into our ELMS-Canvas course site at least once every 24-hour period to check your inbox and the Announcements page.

Names/Pronouns and Self-Identifications

The University of Maryland recognizes the importance of a diverse student body, and we are committed to fostering inclusive and equitable classroom environments. I invite you, if you wish, to tell us how you want to be referred to in this class, both in terms of your name and your pronouns (he/him, she/her, they/them, etc.). Keep in mind that the pronouns someone uses are not necessarily indicative of their gender identity. Visit trans.umd.edu to learn more.

Additionally, it is your choice whether to disclose how you identify in terms of your gender, race, class, sexuality, religion, and dis/ability, among all aspects of your identity (e.g., should it come up in classroom conversation about our experiences and perspectives) and should be self-identified, not presumed or imposed. I will do my best to address and refer to all students accordingly, and I ask you to do the same for all of your fellow Terps.

Communicating with your Peers

With a diversity of perspectives and experience, we may find ourselves in disagreement and/or debate with one another. As such, it is important that we agree to conduct ourselves in a professional manner and that we work together to foster and preserve a virtual classroom environment in which we can respectfully discuss and deliberate controversial questions. I encourage you to confidently exercise your right to free speech—bearing in mind, of course, that you will be expected to craft and defend arguments that support your position. Keep in mind, that free speech has its limit and this course is NOT the space for hate speech, harassment, and derogatory language. I will make every reasonable attempt to create an atmosphere in which each student feels comfortable voicing their argument without fear of being personally attacked, mocked, demeaned, or devalued.

Any behavior (including harassment, sexual harassment, and racially and/or culturally derogatory language) that threatens this atmosphere will not be tolerated. Please alert me immediately if you feel threatened, dismissed, or silenced at any point during our semester together and/or if your engagement in discussion has been in some way hindered by the learning environment.

Netiquette Policy

Netiquette is the social code of online classes. Students share a responsibility for the course’s learning environment. Creating a cohesive online learning community requires learners to support and assist each other. To craft an open and interactive online learning environment, communication has to be conducted in a professional and courteous manner at all times, guided by common sense, collegiality and basic rules of etiquette.

Grading

Grade Breakdown

Assignment	Percentage %
Homework	0%
Quizzes (3)	30%
Lecture Assignments (4)	20%
Residential Energy Audit Project	20%
Commercial Building (Datacenter) Energy Audit Project	30%
Total	100%

Course Assignments

Homework

Homework will be assigned but will not be collected. Homework solutions will be posted on the course website per the schedule listed on the syllabus. You are urged to work on the problems yourself before looking at the solutions.

Quizzes

Quizzes are normally designed for a duration of 30 minutes. It may include questions about both statement type and problem-to-solve type. Thus, you need to have your calculator with you. You need to show your work clearly. This is important for all quizzes, exams, projects, and other assignments to avoid losing points that otherwise are deserved. Grading errors due to lack of clarity in the paper will be strictly your responsibility.

Lecture Assignments

There will be 4 lecture assignments based on the topics discussed in week 10, 11, 12 and 13 respectively. The purposed of these assignments will be to gauge the students’ learnings from the content discussed in those weeks (from instructor and the invited lectures). As part of the assignment, will provide a 2-page summary on the learnings from the “hard to abate” sector lectures covered in the previous week. Students will be encouraged to provide their own insights on possible methods to address the challenges in those sectors

Projects

One residential building will be assigned for energy audit and will require the submission of a PowerPoint presentation report. This can include the student’s own residence. A simplified datacenter will be assigned for the commercial energy audit problem.

Grading of Assignments

All quizzes, lecture assignments and projects will be graded by the instructor(s). Depending on the class size, you should expect the grades to be available within 10 days of submitting your assignment. If you have any questions please contact the lead instructor. For every assignment, the grade rubric will be described on ELMS. You have a week to review and dispute any grade.

Grade Computation

All assessment scores will be posted on ELMS/Canvas page. If you would like to review any of your grades (including the exams), or have questions about how something was scored, please email me to schedule a time for us to meet and discuss.

It is expected that you will submit work by the deadline listed in the syllabus and/or on ELMS-Canvas. Late work will be penalized according to the late work policy described in the **Course Policies and Procedures** section below.

Grade Disputes: I am happy to discuss any of your grades with you, and if I have made a mistake, I will immediately correct it. Any formal grade disputes must be submitted in writing and within one week of receiving the grade.

Please note the total grade that will be automatically calculated on ELMS does not represent your weighted grade. At the end of the course, I will share with you the weighted grade based on the formula above. The weighted grade will be mapped to the letter grade.

The final mapping of the weighted grade to the letter grade will be made available based on the distribution of the weighted grade. Please note that mapping will be final to be fair to all students. If there is a cutoff at 80%, a grade of 79.99% would not be approximated to 80%.

Final Grade Cutoffs									
+	97.00%	+	87.00%	+	77.00%	+	67.00%	+	
A	94.00%	B	84.00%	C	74.00%	D	64.00%	F	<60.0%
-	90.00%	-	80.00%	-	70.00%	-	60.00%	-	

Course Schedule

Week #	Topic	Deliverable
1	<ul style="list-style-type: none"> Introduction of the course and review of relevant fundamentals Overview of the US energy industry and decarbonization challenges across major industrial sectors 	
2	<ul style="list-style-type: none"> Renewable electricity production and utilization (Solar) Renewable electricity production and utilization (Wind) 	HW #1
3	<ul style="list-style-type: none"> Renewable energy production and utilization (Hydropower, Geothermal) Renewable energy production and utilization (Carbon Neutral Biofuels, Hydrogen) 	
4	<ul style="list-style-type: none"> Economics of fuels and electricity markets & Utility Rate Schedules Building energy consumption, its major sources and energy economics analysis 	HW #2, Quiz #1
5	<ul style="list-style-type: none"> Energy Audit Procedures and Energy Benchmarking/ Energy Use Intensity (EUI) Residential Energy Audit, Lighting Audit 	HW #3, Residential Audit Project Assigned
6	<ul style="list-style-type: none"> Building Envelope Audit HVAC Audit I and II 	Residential Audit 25% Complete
7	<ul style="list-style-type: none"> Boiler/steam systems principles & energy-saving technologies LEED & Energy Star Standards, Building Automation and Control Systems 	HW #4, Quiz #2, Residential Audit 50% Complete
8	<ul style="list-style-type: none"> Mid-course Questions and Answers 	Presentation of Residential Audits: 5:00 – 7:00 PM Residential Audit Reports Due by 11:00 PM
9	<ul style="list-style-type: none"> Energy Audit & Thermal Management of Data Centers/mission critical facilities Commercial Audit Project walkthrough/site visit, On campus datacenter 	Quiz #3, Commercial Audit Project Assigned
10	<ul style="list-style-type: none"> Data Center Energy Modeling (AR) 	Commercial Audit 25% Complete

	<ul style="list-style-type: none"> Invited lecture: Technology options for data center energy efficiency (Dr. Peter deBock, DOE) 	
11	<ul style="list-style-type: none"> Cement and concrete decarbonization Technology options for cement and concrete sector decarbonization (TBD) 	Lecture Assignment #1
12	<ul style="list-style-type: none"> Iron and steel decarbonization Invited lecture: Technology options for iron and steel sector decarbonization (Dr. Cory Phillips, DOE) 	Lecture Assignment #2, 50% of Commercial Audit Project Status Presentations
13	<ul style="list-style-type: none"> Petrochemicals and chemicals decarbonization Invited lecture: Technology options for chemicals sector decarbonization (Larrie Brown, Energetics/DOE) 	Lecture Assignment #3
14	<ul style="list-style-type: none"> Aviation and Maritime decarbonization Invited lecture: Technology options for aviation sector decarbonization (Dr. Xin Wu, DOE) 	Lecture Assignment #4, 75% Commercial Audit Project Status presentations
15	<ul style="list-style-type: none"> Emerging technologies for energy sustainability (Nuclear, energy storage etc.) Overview of the course: Questions/Discussions session 	<p>Presentation of Commercial Audit Projects 5:00 -7:00 PM</p> <p>Both the Written and PowerPoint versions of the Commercial Audit report are due by 11 PM, Friday May 6th</p>

Commented [MO1]: I have invited Joe King, awaiting his response

Note: This is a tentative schedule, and subject to change as necessary – monitor ELMS-Canvas for current deadlines. In the unlikely event of a prolonged university closing, or an extended absence from the university, adjustments to the course schedule, deadlines, and assignments will be made based on the duration of the closing and the specific dates missed.

Course Policies and Procedures

The University of Maryland’s conduct policy indicates that course syllabi should refer to a webpage of course-related policies and procedures. For a complete list of graduate course related policies, visit the [Graduate School website](#). Below are course-specific policies and procedures which explain how these Graduate School policies will be implemented in this class.

Satisfactory Performance

The Graduate School expects students to take full responsibility for their academic work and academic progress. The student, to progress satisfactorily, must meet all the academic requirements of this course. Additionally, each student is expected to complete all readings and any preparatory work before each class session, come to class prepared to make substantive contributions to the learning experience, and to proactively communicate with the instructor when challenges or issues arise.

Questions about Assignments

Please ask all questions you may have about an assignment by 12:00 PM the day before the assignment is due. Any questions asked after that time may not be answered in time for you to make changes to your work.

Late Work Policy

All students are given 48 hours of grace period that they can use as they wish during the semester. After this period is exhausted, the late policy below will take effect. For example, if you were late 24 hours for each of the first two assignments, and 13 hours for the third assignment, there is no penalty for the first two assignments, and you will be deducted 10% of the grade of the third assignment.

- Less than 1 hour late: No penalty (one hour grace period)
- 1-24 hours late: 20% penalty
- 24-48 hours late: 40% penalty
- ...etc. (20% for every additional 24 hours late)

Religious Observance

It is the student's responsibility to inform the instructor of any intended absences for religious observances in advance. Notice should be provided as soon as possible but no later than the end of the schedule adjustment period.

Academic Integrity

The University's Code of Academic Integrity is designed to ensure that the principles of academic honesty and integrity are upheld. In accordance with this code, the University of Maryland does not tolerate academic dishonesty. Please ensure that you fully understand this code and its implications because all acts of academic dishonesty will be dealt with in accordance with the provisions of this code. All students are expected to adhere to this Code. It is your responsibility to read it and know what it says, so you can start your professional life on the right path. **As future professionals, your commitment to high ethical standards and honesty begins with your time at the University of Maryland.** Please visit the [Office of Graduate Studies' full list of campus-wide policies](#) and reach out if you have questions.







For this course specifically, unless otherwise stated, all quizzes, exams, programming assignments and any other assignments are individual assignments: collaboration is not permitted unless explicitly stated on the assignment handout. Students may discuss among themselves concepts pertaining to the programming assignments. However, at no point should any code, pseudocode, or anything that resembles code be exchanged or copied from a website, a peer, an AI generated website.

Students should write the pledge of honor on all submitted assignments, projects, and exams:

"I pledge on my honor that I have not given or received any unauthorized assistance on this exam/assignment."

To help you avoid unintentional violations, **the following table** lists levels of collaboration that are acceptable for each graded exercise. Each assignment will contain more specific information regarding acceptable levels of collaboration. Please note that if you are gathering information from online/AI tools, please reference the tools

and ensure accuracy before submitting the information. DO NOT USE AI tools to write your lecture assignments or reports for you!

	 OPEN NOTES	 USE BOOK	 LEARN ONLINE	 GATHER CONTENT With AI	 ASK FRIENDS	 WORK IN GROUPS
Homework Assignments	✓	✓	✓	---	---	---
Quizzes	✓	✓	✓	---	---	---
Lecture Assignments	✓	✓	✓	✓	✓	---
Residential Energy Audit Project	✓	✓	✓	✓	✓	✓
Commercial Energy Audit Project	✓	✓	✓	✓	✓	✓

Course Evaluation

Please submit a course evaluation through Student Feedback on Course Experiences in order to help faculty and administrators improve teaching and learning at Maryland. All information submitted to Course Experiences is confidential. Campus will notify you when Student Feedback on Course Experiences is open for you to complete your evaluations at the end of the semester. Please go directly to the [Student Feedback on Course Experiences](#) to complete your evaluations. By completing all of your evaluations each semester, you will have the privilege of accessing through Testudo the evaluation reports for the thousands of courses for which 70% or more students submitted their evaluations.

Copyright Notice

Course materials are copyrighted and may not be reproduced for anything other than personal use without written permission.

Tips for Succeeding in this Course

1. **Participate.** I invite you to engage deeply, ask questions, and talk about the course content with your classmates. You can learn a great deal from discussing ideas and perspectives with your peers and professor. Participation can also help you articulate your thoughts and develop critical thinking skills.
2. **Manage your time.** Students are often very busy, and I understand that you have obligations outside of this class. However, students do best when they plan adequate time that is devoted to course work. Block your schedule and set aside plenty of time to complete assignments including extra time to handle any technology related problems.
3. **Login regularly.** I recommend that you log in to ELMS-Canvas several times a week to view announcements, discussion posts and replies to your posts. You may need to log in multiple times a day when group submissions are due.

4. **Do not fall behind.** This class moves at a quick pace and each week builds on the previous content. If you feel you are starting to fall behind, check in with the instructor as soon as possible so we can troubleshoot together. It will be hard to keep up with the course content if you fall behind in the pre-work or post-work.
5. **Use ELMS-Canvas notification settings.** Pro tip! Canvas ELMS-Canvas can ensure you receive timely notifications in your email or via text. Be sure to enable announcements to be sent instantly or daily.
6. **Ask for help if needed.** If you need help with ELMS-Canvas or other technology, IT Support. If you are struggling with a course concept, reach out to me and your classmates for support.

Student Resources and Services

Taking personal responsibility for your learning means acknowledging when your performance does not match your goals and doing something about it. I hope you will come talk to me so that I can help you find the right approach to success in this course, and I encourage you to visit the [Counseling Center's Academic Resources](#) to learn more about the wide range of resources available to you. Below are some additional resources and services commonly used by graduate students. For a more comprehensive list, please visit the Graduate School's [Campus Resources Page](#).

Accessibility and Disability Services

The University of Maryland is committed to creating and maintaining a welcoming and inclusive educational, working, and living environment for people of all abilities. The University of Maryland is also committed to the principle that no qualified individual with a disability shall, on the basis of disability, be excluded from participation in or be denied the benefits of the services, programs, or activities of the University, or be subjected to discrimination. The [Accessibility & Disability Service \(ADS\)](#) provides reasonable accommodations to qualified individuals to provide equal access to services, programs and activities. ADS cannot assist retroactively, so it is generally best to request accommodations several weeks before the semester begins or as soon as a disability becomes known. Any student who needs accommodations should contact me as soon as possible so that I have sufficient time to make arrangements.

For assistance in obtaining an accommodation, contact Accessibility and Disability Service at 301-314-7682, or email them at adsfrontdesk@umd.edu. Information about [sharing your accommodations with instructors, note taking assistance](#) and more is available from the [Counseling Center](#).

Writing Center

Everyone can use some help sharpening their communication skills (and improving their grade) by visiting [The Graduate School's Writing Center](#) and schedule an appointment with them. Additionally, international graduate students may want to take advantage of the Graduate School's free [English Editing for International Graduate Students \(EIGS\) program](#).

Health Services

The University offers a variety of physical and mental health services to students. If you are feeling ill or need non-emergency medical attention, please visit the [University Health Center](#).

If you feel it would be helpful to have someone to talk to, visit [UMD's Counseling Center](#) or [one of the many other mental health resources on campus](#).

Notice of Mandatory Reporting

Notice of mandatory reporting of sexual assault, sexual harassment, interpersonal violence, and stalking: As a faculty member, I am designated as a “Responsible University Employee,” and I must report all disclosures of sexual assault, sexual harassment, interpersonal violence, and stalking to UMD’s Title IX Coordinator per University Policy on Sexual Harassment and Other Sexual Misconduct.

If you wish to speak with someone confidentially, please contact one of UMD’s confidential resources, such as [CARE to Stop Violence](#) (located on the Ground Floor of the Health Center) at 301-741-3442 or the [Counseling Center](#) (located at the Shoemaker Building) at 301-314-7651.

You may also seek assistance or supportive measures from UMD’s Title IX Coordinator, Angela Nastase, by calling 301-405-1142, or emailing titleIXcoordinator@umd.edu.

To view further information on the above, please visit the [Office of Civil Rights and Sexual Misconduct's](#) website at ocrsm.umd.edu.

Basic Needs Security

If you have difficulty affording groceries or accessing sufficient food to eat every day, or lack a safe and stable place to live, please visit [UMD’s Division of Student Affairs website](#) for information about resources the campus offers you and let me know if I can help in any way.

Veteran Resources

UMD provides some additional supports to our student veterans. You can access those resources at the office of [Veteran Student life](#) and the [Counseling Center](#). Veterans and active duty military personnel with special circumstances (e.g., upcoming deployments, drill requirements, disabilities) are welcome and encouraged to communicate these, in advance if possible, to the instructor.