Course Syllabus

Integrated Assessment Modeling—Examining Strategies for Meeting Energy and Environmental Goals

Instructor: Dan Loughlin, Ph.D. (Duke BSE '93; Adjunct Professor, Duke Univ.)

Lectures: 4:40-5:15 MW, 1104 Grainger Hall

Assignments are typically due on Thursdays, 11:59 PM, although there may be exceptions

Office hours on Zoom by appointment

Course objectives

- Apply an integrated assessment model, GCAM, to a real-world problem
- Learn how to design and conduct model-based experiments for applications such as evaluating a technology or policy
- Explore an iterative approach to problem solving in which one learns more about the problem during the solution process
- Learn how a model's scope, structure, and parameterization affect its operation and the questions to which it can be applied
- Interpret modeling results in the context of the strengths and limitations of a model
- Improve skills in presenting scientific results

Background

The United States is at an energy technology and policy crossroads. From 2009 to 2023, the share of electricity produced from coal combustion decreased from 45% to 16%, while the share met by natural gas increased from 23% to 43%. Over the same period, the costs of wind and solar power decreased dramatically, leading to combined market share of 26% in 2023. The transportation sector is also being transformed. Where electric vehicles (EVs) largely were a novelty in 2010, their share of new car sales in 2023 reached nearly 8% nationally. Developments in the buildings sector include broader adoption of LED lightbulbs, hybrid hot water heaters, geothermal heat pumps, and green roofs. There are also emerging and growing demands for electricity - including power data centers and artificial intelligence. These uses will soon grow to more than 10% of U.S. electricity demand, exceeding 50% in some states. This increasing demand is changing the economics of operating existing coal powerplants, potentially delaying shutdowns.

These rapid transformations have the potential to provide both environmental opportunities and challenges. Since carbon dioxide and air pollutants are often co-emitted by the same sources, efforts to decarbonize can yield air quality co-benefits. Furthermore, transitioning away from thermo-electric technologies (e.g., coal and nuclear) significantly reduces demands for water. However, some decarbonization pathways can yield local disbenefits by shifting the location of pollution from one economic sector to another or from one location to another. For example, the net emission impacts of EVs are determined by direct impacts (e.g., emission savings in the transportation sector), indirect or secondary impacts (e.g., changes in electric sector and refining emissions), and tertiary impacts (e.g., life-cycle emissions and those from energy price-induced fuel switching). Many of these impacts are not stationary in time: gasoline-fueled vehicles are expected to emit less over time as a result of EPA mobile vehicle regulations, and emissions from the electric sector into the future will depend on how the composition of that sector changes.

Integrated Assessment Models provide an avenue for understanding the emissions and environmental impacts of energy transformations. They allow us to examine primary, secondary, and tertiary emission impacts, consider issues such as cross-border energy trade and emissions leakage, and explore different assumptions about factors such as technology development and population and economic growth. IAMs also provide a computational laboratory in which we can examine the efficacy of both existing and potential policies in meeting environmental goals, potentially resulting in more cost-effective and robust management strategies that avoid unintended consequences.

The primary objective of this class is to provide students with a hands-on opportunity to use an Integrated Assessment Model, the open-source Global Change Analysis Model with state-level resolution (GCAM-USA) (http://jgcri.github.io/gcam-doc/). GCAM-USA simulates the co-evolution of the global energy, water, land, and climate systems through 2100, doing so with 32 global regions and 50 state-level resolution for the United States. A major focus of GCAM-USA is energy, and the model represents energy supply, demand, and technology adoption in buildings, industry, and transportation. Students will apply GCAM-USA using methods such as sensitivity and scenario analysis. A secondary objective is to give students an opportunity to learn about modeling and to determine whether this is an interesting career path for them.

GCAM-USA is an “IPCC-class model”, having been used in support of numerous global climate change mitigation planning activities. Being able to use it in a classroom setting is a unique opportunity. That said, GCAM-USA is a complicated model to learn and apply. To facilitate its use, students will use the GLIMPSE-CE decision support software, derived from EPA’s GLIMPSE (https://epa.gov/glimpse). GLIMPSE-CE provides an easy-to-use user interface for GCAM, facilitating implementing policies, developing and running scenarios and visualizing results. By making running the model easier, students can focus more on understanding how the model works, experimental design, and on interpreting results.

GLIMPSE was released to the public by EPA in 2023. In 2024, several states (e.g., GA, TN, MN, and MD) used GLIMPSE and/or GCAM-USA in their climate planning efforts. In addition to states, GLIMPSE users now include faculty and students at nearly a dozen universities, as well as several consultants, environmental non-profits, and financial institutions. GLIMPSE-CE is derived from GLIMPSE and is being released in 2025. It incorporates a newer version of GCAM and includes a number of usability improvements. The course instructor, Dan Loughlin, was the lead developer of GLIMPSE while at the U.S. EPA and is now the lead developer for GLIMPSE-CE.

GLIMPSE-CE supports GCAM users in activities including:

- Developing representations of policy goals or measures (e.g., technology market share targets, technology or fuel subsidies, pollutant taxes or caps)
- Constructing and executing scenarios
- Monitoring GCAM progress and assisting with debugging
- Visualizing key model outputs and identifying differences in those outputs from one scenario to another
- Archiving the inputs and outputs associated with particular scenarios

GLIMPSE-CE currently operates on Windows PCs and Linux workstations with 16 GB or more of RAM. This course will meet in a computer lab where students can bring their own laptops or use Virtual Computers provided by the university.

Format

This course, which will meet in person, consists of lectures, weekly assignments, and individual or group projects with presentations.

A major component of the course is the project. Students will participate in individual or team projects that will culminate with each team presenting its findings. Students are able to choose topics of relevance to their own interests, so long as those investigations are supported by GLIMPSE.

Past projects have included topics such as assessments of:

- North Carolina joining the Regional Greenhouse Gas Initiative

- Rollbacks to many of the key provisions of the Inflation Reduction Act
- Economy-wide vs. sector-specific GHG caps in California
- System-wide and emissions impacts of reduced beef consumption
- Energy and emissions implications of climate-motivated population migration
- Comparative assessment of mitigation options in the US, China, and India
- Impacts of expanded water access in Northern Africa as a result of infrastructure improvements
- Effect of biomass in mitigation schemes on global food prices

Required texts

There is no required textbook for this course. All readings will be available online via the Duke library.

More on instructor

The instructor for this course is Dr. Dan Loughlin. Dan recently retired from federal service after 22 years within the U.S. Environmental Protection Agency's Office of Research and Development. Dan's specialties include energy system modeling, technology assessment, estimating air pollutant and greenhouse gas emissions for technology and policy scenarios, and sensitivity and uncertainty analyses. Dan's research has largely focused on the intersection of air quality, climate, and energy (Daniel H. Loughlin - Google ScholarLinks to an external site.). He has been an Adjunct Professor with the Nicholas School of the Environment since 2019 and also holds academic appointments at the North Carolina State University and at University of North Carolina at Chapel Hill and was an author on two National Climate Assessments.

Grading

- 10% Class participation, including attendance and participation in discussions
- 50% Assignments (10)
- 40% Individual/team project and presentation

Schedule (subject to change)

- Jan 7 (W): Introduction to 568S
- Jan 11 (M): Modeling concepts and taxonomy

- Jan 13 (W): Integrated Assessment Models
- Jan 19 (M): No class
- Jan 21 (W): Global Change Analysis Model
- Jan 26 (M): GLIMPSE & GCAM installation
- Jan 28 (W): GLIMPSE overview and application
- Feb 2 (M): Exploring GCAM-USA results
- Feb 4 (W): How does GCAM work? Part 1
- Feb 9 (M): How does GCAM work? Part 2
- Feb 11 (W): Designing an experiment
- Feb 16 (M): Sensitivity and scenario analysis
- Feb 18 (W): In-class scenario activity, day 1
- Feb 23 (M): In-class scenario activity, day 2
- Feb 25 (W): In-class scenario activity, day 3
- Mar 2 (M): Class project overview/Project brainstorming session
- Mar 4 (W): Dos and Don'ts for presentations / pivot tables
- Mar 9 (M): No class
- Mar 11 (W): No class
- Mar 16 (M): IPCC and IAMs
- Mar 18 (W): EMF and intermodal comparisons
- Mar 23 (M): GCAM-USA and climate planning
- Apr 1 (W): Into the weeds - folder structure, how GCAM and GLIMPSE interact
- Apr 6 (M): Into the weeds - the GCAM data system
- Apr 8 (W): Wrapping things up
- Apr 13 (M): Class presentations day 1
- Apr 15 (W): Class presentations day 2

Assignments

We will have a mix of in-class and out-of-class assignments. Please see the "Assignments" area of Canvas for details.

Course Communication

I will rely on Canvas as the primary means of communicating course updates and assignments. Please ensure that you have enabled emails for Canvas updates and/or are checking the site regularly. 24/7 support is available for Canvas if you encounter technical difficulties. For immediate assistance with other learning technologies, system errors/outages, or your NetID account and password, contact the OIT Service Desk.

Please feel free to email me if you have issues with assignments or other aspects of class. If possible, please provide all relevant information, including what you have done to resolve the issue yourself. Having an in-class buddy could also be useful. If you would like to schedule a one-on-one meeting, please email me and we can find a time to Zoom since I do not have an office on campus.

Mutual Learning Agreements

Mutual learning – learning that occurs between peers – is an important part of higher education. I encourage students to bring their knowledge, histories, and emotional selves to this course because doing so enriches classroom learning for everyone. To facilitate this learning, I ask that students commit to a set of learning agreements. I propose the following (adapted from those developed by Dr. Cathy Gastelum) to start, and encourage students to recommend addition, adaptions, and even subtractions in this living document.

1. Our classroom is a confidential space: Nothing shared within it will be shared outside of it (unless de-identified).
2. We won't use stereotypes or epithets to refer to individuals or groups (e.g., "Even your grandmother could understand…").
3. We will approach diversity of identities, perspectives, and ideas with curiosity rather than judgment.
4. We will try to locate common ground among perspectives, before identifying differences.
5. We will critique ideas, not people.
6. As listeners, we will presume good intentions (where possible) and remember that mistakes are part of learning.

7. As speakers, we will receive and be grateful for feedback about the impact of your comments (which might not align with our intentions).
8. We will try to maintain awareness of socioeconomic and cultural differences among us that might shape our perspectives, discussion posts, and contributions to synchronous conversation.
9. We will work to be aware of how much we are contributing to class discussions to make sure that everyone is able to participate. Those of us who regularly participate in class discussions will try to make space for those of us who feel more reluctant to participate. Those of us who tend not to participate as much will challenge ourselves to take up space in class discussions as much as possible.

If you feel a peer has violated one of the mutual learning agreements, I encourage you to address your peer directly if you feel comfortable doing so. Whether or not you feel comfortable addressing your peer, please feel empowered to come talk to me about it.

Academic Standards:

All students must adhere to the Duke Community Standard (DCS): Duke University is a community dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Citizens of this community commit to reflect upon and uphold these principles in all academic and non-academic endeavors, and to protect and promote a culture of integrity.

To uphold the Duke Community Standard, students agree:

- I will not lie, cheat, or steal in my academic endeavors.
- I will conduct myself honorably in all my endeavors; and
- I will act if the Standard is compromised.

Regardless of course delivery format, it is the responsibility of the student to understand and follow Duke policies regarding academic integrity, (e.g., completing one's own work, following proper citations of sources, and adhering to guidance around group work, and more). Ignoring these requirements is a violation of the Duke Community Standard. Any questions and/or concerns regarding academic integrity can be directed to the Office or Student Conduct and Community Standards at conduct@duke.edu.

AI Policy:

You may use GenAI tools for brainstorming, outlining, organization, code, and copy-editing, but not for final drafts of your writing or presentations. All assignments in which you used AI should include a 1–3 sentence “AI Use Note” that list the tool(s) you used and a summary of prompts, outputs, and their integration into your work. You will be responsible for fact-checking and ensuring the integrity of citations. If you are assigned a reading, please read the reading first if you plan to use AI to summarize.

Resources to Support Student Success

If you are having trouble completing assignments or understanding the materials, please reach out by sending me an email or visiting office hours. The Academic Resource Center (ARC) offers services to support students academically during their undergraduate careers at Duke. The ARC can provide support with time management, academic skills and strategies, course-specific tutoring, ADHD/LD coaching, and more. ARC services are available free to any Duke undergraduate students, studying any discipline. Contact: (919) 684-5917 or theARC@duke.edu

Mental Health and Wellness Resources

Mental health and wellness should always come first. The university offers resources to support students in managing daily stress and self-care (a few of which listed below).

DuWell provides Moments of Mindfulness (stress management and resilience building) and meditation programming (Koru workshop) to assist students in developing a daily emotional well-being practice. All are welcome and no experience is necessary.

If your mental health concerns and/or stressful events negatively affect your daily emotional state, academic performance, or ability to participate in your daily activities, many resources are available.

- DukeReach provides services for students who are experiencing significant challenges relating to mental health, physical health, social adjustment, and/or a variety of other stressors.
- Counseling & Psychological Services (CAPS) services include individual and group counseling services, psychiatric services, and workshops. To initiate services, walkin/call-in 9:00 AM – 4:00 PM (M/W/Th/F) and 9:00 AM – 6:00 PM Tuesdays. CAPS also provides referral to off-campus resources for specialized care. Contact: (919) 660-1000
- TimelyCare (formally known as Blue Devils Care) is an online platform that is a convenient, confidential, and free way for Duke students to receive 24/7 mental health support through TalkNow and scheduled counseling.