GGS621
Climate and Environmental Scenario Assessment Methodology

Syllabus Fall 2023 [Draft]

Course Instructor:
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Course Meeting Times
Lectures: Wednesday 1:00pm – 3:45pm (location N1-112)

Office Hours
Thursday 1:30pm – 3:00pm (email appointment; location Zoom or E3-1-3426)

Course Description
'Climate and Environmental Scenario Assessment Methodology' is an interdisciplinary course that provides tools to develop and assess future scenarios of climate and environmental change. Students will learn about the key issues surrounding climate change and integrated assessment modeling tools that can generate scenarios to support energy, environmental, climate, and technology policy decision-making. In particular, students will acquire the theoretical and practical foundations of integrated assessment research, including its history, evolution, application to scenario assessment, strengths and limitations, role in the policy-making process, and new directions in integrated assessment research. This course will be useful for students conducting research in areas where integrated assessment modeling is used, such as climate science and environmental policy.

Course Objectives
- Understand the fundamentals of integrated assessment modeling (IAM).
- Understand the basic characteristics of energy, water, and land systems, their interlinkages, and the implications of those interlinkages for a range of environmental goals and policies.
- Learn how to frame science and policy questions that IAM is well-suited to answer.
- Learn to use IAM, and interpret and communicate IAM outputs, to address science and/or policy relevant questions.

Course Evaluation

- **Paper Critique (20%)**: Each student will choose one IAM journal paper to peer-review and present the key findings and critical review of the paper.
- **Mid-term paper (20%)**: Students will develop a short proposal (3-5 pages) on the final research project for this class, including the research question and methodology.
- **Final project (40%)**: Students will work individually on a research project, apply an IA modeling tool to inform a policy question and support decision making based on results. Project will be evaluated based on in-class presentation and a written paper.
- **Class participation (20%)**: Students will participate in class discussions and attend hands-on sessions. Students will also submit modeling exercise results.

Grades

All assessment scores will be posted on the course page. Late work will not be accepted for course credit, so please plan to have it submitted well before the scheduled deadline. Any formal grade disputes must be submitted in writing and within one week of receiving the grade.

Required Resources

- **Course Website:** All course content will be distributed via course page. Readings, Slides, Assignments, etc. will be organized here by module. IMPORTANT announcements will be made via course announcements. You must make sure that your email & announcement notifications (including changes in readings, assignments and/or due dates) are enabled so you do not miss any messages. You are responsible for checking your email with regular frequency.

Course Structure

This course has a weekly in-person session that are mandatory. The in-person nature of this class will push you to take an active role in the learning process. You will do this by engaging and collaborating with other students and the instructors on a regular basis, both in live sessions, and through group work and activities.

Tips for Success in the course

1. **Participate.** Discussions and group work are a critical part of the course. 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.** Make time for your online learning and participation in discussions each week. Give yourself plenty of time to complete assignments including extra time to handle any technology related problems.
3. **Login regularly.** Log in to class page several times a week to view announcements, discussion posts and replies to your posts. You may need to log in multiple times per 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 week. It will be hard to keep up with the course content if you fall behind in the pre-work or post-work.
5. **Ask for help if needed.** If you are struggling with a course concept, reach out to me, and your classmates, for support.

Academic Integrity

The University's Code of Academic Integrity is designed to ensure that the principles of academic honesty and integrity are upheld. All students are expected to adhere to this Code. The University does not tolerate academic dishonesty. All acts of academic dishonesty will be dealt with in accordance with the provisions of this code.

Accommodations for Students with Special Needs

Any student with special needs should bring this to the attention of the instructor as soon as possible. This notification should be provided no later than the second week of the class.

Adjustments in the Syllabus

The content of the syllabus is subject to change to conform to the needs of the course, and any such changes will be announced in class. It is the responsibility of each student to become informed of any changes. Regular attendance provides up-to-date and first-hand information.

Course Schedule

Date	Lecture Topic (w/ Guest Speaker)	Pre-Class Reading	What's Due
8/30	Introduction to IAM	Reading 1	
9/6	Foundations of IAM	Reading 2	Assignment 1
9/13	Energy System	Reading 3	
9/20	Land System	Reading 4	Assignment 2
9/27*	Emission System (Prof. Yang Ou)	Reading 5	Assignment 3
10/4	Water System	Reading 6	Assignment 4
10/11	Food-Energy-Water Nexus	Reading 7	
10/18	Mid-Term: Project Proposal		Project proposal
10/25	IAM in International Climate Policies	Reading 8	
11/1	Standardized Scenarios	Reading 9	Assignment 5
11/8	Multi-model Comparison	Reading 10	Assignment 6
11/15*	IAM in National Strategies (TBD)	Reading 11	Assignment 7
11/22	Mitigation and other SDGs	Reading 12	Assignment 8
11/29	Uncertainty in IAM and Climate Change	Reading 13	
12/6	Emerging and Future Directions	Reading 14	

12/13	Final project presentation 1		**Presentation**

Pre-class readings will be posted one week before the lecture date.
Assignments will be distributed at the end of each class and will be due before the next class (see specific due dates above). Instructions on each assignment will be provided.

Week 1. Introduction to Integrated Modeling and Assessment: what are the "big issues" in this field, what are IA models, why are IA research and models valuable for understanding integrated systems, and what IA models do (and what they don't).

- **Reading 1:**
  - Carbon Brief Explainers, Q&A: How 'integrated assessment models' are used to study climate change, 2018.
  - Edmonds, J. and J. Reilly. 1983. A Long-Term, Global, Energy-Economic Model of Carbon Dioxide Release From Fossil Fuel Use, ***Energy Economics***, ***5***(2):74-88.
  - Volker Krey. Global energy-climate scenarios and models: a review. *WIREs Energy Environ* 2014, 3:363–383.
- **Assignment 1:** Setup GCAM on a computer (laptop, cluster, or cloud), and run a GCAM reference scenario

Week 2. Foundations of Integrated Assessment: history, evolution of the tool and overall structure, types of applications and examples.

- **Reading 2:**
  - John Weyant. Some Contributions of Integrated Assessment Models of Global Climate Change. *Review of Environmental Economics and Policy*, Volume 11, Issue 1, Winter 2017, Pages 115–137.
  - Fisher-Vanden, K. and Weyant, J., 2020. The Evolution of Integrated Assessment: Developing the Next Generation of Use-Inspired Integrated Assessment Tools. *Annual Review of Resource Economics*, *12*, pp.471-487.
- **Assignment 2:** Run a GCAM decarbonization scenario

Week 3. Energy System: energy process at the regional and global scales, energy transition and climate mitigation, climate impacts on energy demand and supply.

- **Reading 4:**
  - GEA, 2012: *Global Energy Assessment - Toward a Sustainable Future*, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria.
    - Global Energy Assessment Chapter 1 (background information)
    - Global Energy Assessment Chapter 16
  - Iyer, G., Clarke, L., Edmonds, J. et al. Improved representation of investment decisions in assessments of CO2 mitigation. *Nature Clim Change* 5, 436–440 (2015). https://doi.org/10.1038/nclimate2553
- Further reading:
  - Iyer et al. Diffusion of low-carbon technologies and the feasibility of long-term climate targets. T*echnol. Forecast. Soc. Change*, 90 (2015), pp. 103-118, 10.1016/j.techfore.2013.08.025

    - Stegmann, P., Daioglou, V., Londo, M. et al. Plastic futures and their CO2 emissions. Nature 612, 272–276 (2022). https://doi.org/10.1038/s41586-022-05422-5
- **Assignment 3:** Compare GCAM energy queries under the reference and decarbonization scenarios

Week 4. Agriculture and Land-use System: how climate impacts and climate mitigation will both impact land use change and the agriculture system.

- **Reading 5:**
    - Carbon brief In-depth Q&A: The IPCC's special report on climate change and land
    - Calvin, K., M. Wise, P. Kyle, P. Patel, L. Clarke, J. Edmonds. Trade-offs of different land and bioenergy policies on the path to achieving climate targets. Climatic Change (2014) 123:691–704.
    - Nelson et al. Climate change effects on agriculture: Economic responses to biophysical shocks. *PNAS* 111 (9): 3274-3279 (2014).
    - Wise M, Calvin K, Thomson A, Clarke L, Bond-Lamberty B, Sands R, Smith SJ, Janetos A, Edmonds J (2009) Implications of limiting CO2 concentrations for land use and energy. *Science* 324: 1183–1186

- **Assignment 4:** Run a GCAM decarbonization UCT scenario, and explore land and agriculture system responses to different policy designs

Week 5. Greenhouse Gas Emission System: guest lecture on how emissions are assessed in IAMs.

- **Reading 5:**
    - Ou Y., G.C. Iyer, A.A. Fawcett, N.E. Hultman, et al. 2022. "Role of non-CO2 greenhouse gas emissions in limiting global warming." One Earth 5, no. 12:1312-1315.

- **Assignment 5:** Compare non-CO2 emission queries under the reference and decarbonization scenarios.

Week 6. Water System: Reviews the human and natural processes that drive the availability, usage, and scarcity of water across space and time.

- **Reading 6:**
    - *Components of the global water cycle*
        - Oki, T. and Kanae, S., 2006. Global hydrological cycles and world water resources. *Science*, 313(5790), pp.1068-1072.
        - Abbott, B.W., Bishop, K., Zarnetske, J.P., Hannah, D.M., Frei, R.J., Minaudo, C., Chapin III, F.S., Krause, S., Conner, L., Ellison, D. and Godsey, S.E., 2019. A water cycle for the Anthropocene. *Hydrological Processes*, 33(23), pp.3046-3052.
    - *Water and its uses*: D'Odorico, P., Davis, K.F., Rosa, L., Carr, J.A., Chiarelli, D., Dell'Angelo, J., Gephart, J., MacDonald, G.K., Seekell, D.A., Suweis, S. and Rulli, M.C., 2018. The global food-energy-water nexus. Reviews of Geophysics, 56(3), pp.456-531. -- *ONLY READ PAGES 14-19, PER THE TABLE OF CONTENTS*.
    - *Human and natural drivers of scarcity*: Graham, N.T., Hejazi, M.I., Chen, M., Davies, E.G., Edmonds, J.A., Kim, S.H., Turner, S.W., Li, X., Vernon, C.R., Calvin, K. and Miralles-Wilhelm, F., 2020. Humans drive future water scarcity changes across all Shared Socioeconomic Pathways. *Environmental Research Letters*, 15(1), p.014007.
- **Assignment 6:** Explore how water usage changes across sectors and countries over time under different policies. Identify examples of how water is used in agriculture and energy production.

Week 7. Food-Energy-Water Nexus: the linkages and feedbacks between food, energy, and water across space and time, real-world examples and case studies from various projects around the world, such as infrastructure planning and decision support case studies in Latin America.

- **Reading 7:**
  - *Overview*:
    - Scanlon, B.R., Ruddell, B.L., Reed, P.M., Hook, R.I., Zheng, C., Tidwell, V.C. and Siebert, S., 2017. The food-energy-water nexus: Transforming science for society. *Water Resources Research*, 53(5), pp.3550-3556.
    - Ringler, C., Bhaduri, A. and Lawford, R., 2013. The nexus across water, energy, land and food (WELF): potential for improved resource use efficiency?. *Current Opinion in Environmental Sustainability*, 5(6), pp.617-624.
  - *Use (or lack thereof) of FEW nexus concepts in actual planning*: Liu, J., Hull, V., Godfray, H.C.J., Tilman, D., Gleick, P., Hoff, H., Pahl-Wostl, C., Xu, Z., Chung, M.G., Sun, J. and Li, S., 2018. Nexus approaches to global sustainable development. *Nature Sustainability*, 1(9), pp.466-476.
  - *Quantitative assessment of FEW connectivity*: D'Odorico, P., Davis, K.F., Rosa, L., Carr, J.A., Chiarelli, D., Dell'Angelo, J., Gephart, J., MacDonald, G.K., Seekell, D.A., Suweis, S. and Rulli, M.C., 2018. The global food-energy-water nexus. *Reviews of Geophysics*, 56(3), pp.456-531. -- *ONLY READ PAGES 21-33*

Week 8. Mid-Term: Project Proposal

Week 9. Different Integrated Assessment Models and Multi-model Comparison Exercises: a diverse array of the world's cutting edge IA models, and the motivation, process and challenges of multi-model comparison exercises.

- **Reading 8:**
  - Clarke L, Edmonds J, Krey V, Richels R, Rose S, Tavoni M., 2009. International climate policy architectures: overview of the EMF 22 international scenarios. *Energ Econ* 31(suppl 2): S64–S81.
  - Calvin K, Clarke L, Krey V, Blanford G, Jiang K J, Kainuma M, Kriegler E, Lunderer G and Shukla P R, 2012. The role of Asia in mitigating climate change: Results from the Asia modeling exercise Energy Econ. 34 S251–60.
  - CD-LINKS, 2019: Linking Climate and Sustainable Development: Policy insights from national and global pathways. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.
- **Assignment 7:** Students will develop a short summary (2-3 pages) to describe the key insights and uncertainties of a research question based on outputs from multiple IA modeling tools in IAM databases (e.g. IAMC 1.5°C Scenario Explorer and Data hosted by IIASA).

Week 10. Standardized Scenarios, SRES, RCPs, SSPs, SPAs: the design and use of scenarios in modeling and policy analysis.

- **Reading 9:**
  - O'Neill, B.C., Carter, T.R., Ebi, K. et al. Achievements and needs for the climate change scenario framework. Nat. Clim. Chang. 10, 1074–1084 (2020).
  - Carbon Brief Explainer:
    - How 'Shared Socioeconomic Pathways' explore future climate change (2018).
    - The high-emissions 'RCP8.5' global warming scenario (2019).

- Further readings:
  - van Vuuren, D.P., Kriegler, E., O'Neill, B.C. et al. A new scenario framework for Climate Change Research: scenario matrix architecture. Climatic Change 122, 373–386 (2014).
  - O'Neill et al. The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change* 42 (2017) 169–180.

Week 11. IAM in International Climate Policies: contributions of IA research in supporting international climate policy-making.

- **Reading 3:**
  - Weyant, John P., and Jennifer N. Hill. "INTRODUCTION AND OVERVIEW." *The Energy Journal* Vol. 20, Special Issue: The Costs of the Kyoto Protocol: A Multi-Model Evaluation (1999), pp. vii-xliv (38 pages). http://www.jstor.org/stable/23296903
  - Fawcett, A., G. Iyer, L. Clarke, J. Edmonds, N. Hultman, et al. 2015. "Can Paris pledges avert severe climate change?" *Science* 350 (6265), 1168-1169. DOI: 10.1126/science.aad5761
  - van Beek et al. 2020. "Anticipating futures through models: the rise of Integrated Assessment Modelling in the climate science-policy interface since 1970." *Global Environmental Change* 65 (2020): 102191. https://doi.org/10.1016/j.gloenvcha.2020.102191
  - Further readings:
    - IPCC, 2014: Summary for Policymakers. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
    - UNEP Emission Gap report 2020 - Executive Summary.

Week 12. IAM in National Decarbonization Pathways: development of IA models with sub-national details, application of IA research in designing national long-term decarbonization pathways.

- **Readings 11:** to be assigned
  - Kim H., H.C. McJeon, M. Bergero, and J. Eom. 2022. "Integrated Assessment Modeling of Korea's 2050 Carbon Neutrality Technology Pathways." *Energy and Climate Change* 3:100075.

- **Assignment 8:** Run a national GCAM scenario, and plot queries of your choice

Week 13. Climate Mitigation and Other SDGs: using IAM to explore the synergies and tradeoffs between climate mitigation and other sustainable development goals, such as air quality and human health, food security, energy security, and others.

- **Reading 10:**
  - von Stechow, C., Minx, J.C., Riahi, K., Jewell, J., McCollum, D.L., Callaghan, M.W., Bertram, C., Luderer, G. and Baiocchi, G., 2016. 2° C and SDGs: united they stand, divided they fall?. *Environmental Research Letters*, 11(3), p.034022.

- Von Stechow, C., McCollum, D., Riahi, K., Minx, J.C., Kriegler, E., Van Vuuren, D.P., Jewell, J., Robledo-Abad, C., Hertwich, E., Tavoni, M. and Mirasgedis, S., 2015. Integrating global climate change mitigation goals with other sustainability objectives: a synthesis. *Annual Review of Environment and Resources*, 40.
- Iyer, G., Calvin, K., Clarke, L., Edmonds, J., Hultman, N., Hartin, C., McJeon, H., Aldy, J. and Pizer, W., 2018. Implications of sustainable development considerations for comparability across nationally determined contributions. *Nature Climate Change*, 8(2), pp.124-129.

Week 14. Uncertainty in IAMs and Climate Change: exploring uncertainty in the context of IA research and climate change, including uncertainty about climate, socioeconomics, technology, and policy.

- **Reading 12:**
  - *Uncertainty in IAMs*: Lamontagne, J.R., Reed, P.M., Link, R., Calvin, K.V., Clarke, L.E. and Edmonds, J.A., 2018. Large ensemble analytic framework for consequence-driven discovery of climate change scenarios. *Earth's Future*, *6*(3), pp.488-504.
  - Uncertainty in Climate models:
  - *Communication of Uncertainty*: Cooke, R.M., 2015. Messaging climate change uncertainty. *Nature Climate Change*, *5*(1), pp.8-10.

Week 15. Emerging and Future Directions of IAM Research.

- **Readings 13:** to be assigned

Week 16
Final project presentation