Hertie School **Master of International Affairs/Master of Public Policy**
Fall Semester 2021

Course Syllabus, Version 24.06.2021

GRAD-E1370: Artificial intelligence & climate change

Concentration (only relevant for elective courses): Policy Analysis

Lynn Kaack

1. General information

Class time	Fri, 12-14h
Course Format	Onsite/Hybrid This course will be taught onsite under social distancing rules. Students who cannot be on campus will attend sessions online via the platform ClickMeeting/Teams. Clickmeeting/Teams allows for interactive, participatory, seminar-style teaching. Room: 2.61 / online channel
Instructor	Lynn Kaack
Instructor's office	2.41
Instructor's e-mail	kaack@hertie-school.org
Instructor's phone number	
Assistant	Name: Alex Karras Email: karras@hertie-school.org Phone: +49 30 259 219 156 Room: 3.45
Instructor's Office Hours	Wednesdays, 2-3pm (drop in)

Link to MIA and MPP **Module Handbooks**
Link to **Study, Examination and Admission Rules**

Instructor Information:
Lynn Kaack is Assistant Professor of Computer Science and Public Policy at the Hertie School. Her research and teaching focuses on methods from statistics and machine learning to inform climate mitigation policy across the energy sector, and she also has an interest in climate-related AI policy. She is a co-founder and chair of the organization Climate Change AI, and a member of the Austrian Council on Robotics and Artificial Intelligence, which is an advisory board of the Austrian Ministry for Climate Action. Previously she was Postdoctoral Researcher and Lecturer in the Energy Politics Group at ETH Zürich. She obtained a PhD in Engineering and Public Policy and a Master's in Machine Learning from Carnegie Mellon University, as well as a MS and BS in Physics from the Free University of Berlin.

2. Course Contents and Learning Objectives

Course contents:
Artificial intelligence (AI) and climate change are both topics on top of the policy agenda that require a deep technological understanding of the problem space. It does not come as a surprise that these two topics also affect one another in multifaceted ways. This course will explore the relationship of AI and climate change through a policy lens, and ask the question of what policy-makers can do to align AI with climate change goals. Readings will provide students with insights into cutting edge research using AI and machine learning (ML) to address climate change. The course will also cover how AI is deployed in ways that are detrimental to these goals, provide a perspective on systemic effects of AI-driven technologies and their impacts on social well-being, and discuss energy and resource consumption related to AI's computational requirements. Together, we will explore technology assessment and design possible policy instruments. Students will learn how to navigate this intersection of two hot button topics and provide informed and practical advice to policy makers.

Main learning objectives:
This course aims to provide a deep understanding of AI's role in climate change mitigation and adaptation across sectors, and the relationship of AI and climate change more broadly. Based on examples and case studies, students will gain exposure to a wide range of climate-relevant areas where AI can be meaningfully applied, and reflect on the capabilities and limitations of AI in this context. By way of these examples, students will also critically discuss risks and challenges that can arise from AI-driven solutions in this context and reflect about means to reduce such risks. Students will learn criteria for impact assessment of such applications, and explore frameworks for responsible deployment. In this course, students will also learn about the energy consumption of AI, and how the technology might affect greenhouse gas emissions more broadly.
At the end of the course, students will have gained a thorough understanding of the intersection of AI and climate change, such that they will be able to contextualize the ongoing political and public discourse. Students will also have developed a basic understanding of AI and ML methods. The course will provide students both with a conceptual framework and the awareness of practical challenges as relevant for public and private sectors. By exposure to interdisciplinary readings involving ML research, students also build competencies to keep up to date with the latest developments in this fast-evolving area.

Target group:
Students aiming for leadership positions in the public or private sector where they may face decisions around how to assess the benefits and costs of AI applications for addressing climate change, and how to set up policy approaches to shape the impact of AI on the climate. While there are no particular prerequisites to this course, an aptitude for discussing issues across disciplines is expected.

Teaching style:
The course will be taught in an interactive teaching style. The instructor will provide short lectures, with a particular emphasis on the AI and ML concepts that are relevant for the readings and discussions. Every reading will be discussed and reflected in class, and the debate will be led by a student team. Students are encouraged to engage with potentially unfamiliar concepts, discuss ideas encountered in readings and beyond, and reflect critically on opportunities, challenges, and risks of these ideas.

Prerequisites:
There are no prerequisites for joining the course. Some background in statistics, computer science, or machine learning will allow students to gain additional insights into the course materials but this is not a prerequisite to do well in this course.

Diversity Statement:

As you may know, the Hertie School is committed to implementing a Diversity and Inclusion Strategy. In this course, we will discuss a small selection of a wide range of topics of varying relevance to different geographic or political contexts, so a certain bias in the selection cannot be excluded. Students are encouraged to bring up topics that they feel should be discussed and I will make an effort to include those.

3. Grading and Assignments

Composition of Final Grade:

Assignment 1: Reading discussion	Deadline: assigned session	Submit via Moodle	25%
Assignment 2: Parliamentary hearing	Deadline: 26.11.2021	Submit via Moodle	35%
Assignment 3: Policy brief	Deadline: 10.12.2021	Submit via Moodle	30%
Participation grade (if applicable)			10%

Assignment Details

Assignment 1: Reading discussion
In small groups, students will prepare an in-class discussion of the required readings for the assigned session, and moderate the in-class discussion. At a minimum, the group is expected to prepare a set of discussion questions, and hand in a 1-2-page draft plan of the session, containing also a description of main discussion points. Groups are free to design the sessions as they see fit, but should aim for an informative, inclusive, and critical discourse involving the entire class. In the first session the instructor will assign each participant to a session. The draft plan is due by the assigned session.

Assignment 2: Parliamentary hearing
Policy makers have only recently started thinking about how to design policy approaches relating to the intersection of AI and climate change. Towards the end of the course, students will individually prepare an input to a "parliamentary hearing," where they will provide a 5 min talk (without slides) on a course topic of their choosing. The talk should be aimed at an audience of parliamentarians, and will be followed by Q&A. The transcript of the speech must be handed in (either beforehand or by the day after if transcribed from the recording).

Assignment 3: Policy brief
Students (in groups of two) will write a policy brief of 1500-2000 words on an aspect of this course. The topic discussed can either focus on a narrow aspect or the broader picture of AI and climate change, and may relate to the topics the students have discussed in their inputs to the parliamentary hearing. The write-up needs to include a short note for whom they write the policy brief. The information and recommendations should be presented in a very concise way that helps the policy maker relate the content to decisions they might be facing.

Participation grade
Students should come to class not only having read the materials assigned for that day but also prepared to contribute to the discussion of the readings. **Before every class session, the students are required to submit either a clarification or a discussion question in Moodle.** Participation is graded based on consistency and quality, including the complete submission of questions (the nature of questions will not be graded). Students are encouraged to exchange and critique ideas, and make stakeholder and policy relevance a priority.

Late submission of assignments: For each day the assignment is turned in late, the grade will be reduced by 10% (e.g. submission two days after the deadline would result in 20% grade deduction).

Attendance: Students are expected to be present and prepared for every class session. Active participation during lectures and seminar discussions is essential. If unavoidable circumstances arise which prevent attendance or preparation, the instructor should be advised by email with as much advance notice as possible. Please note that students cannot miss more than two out of 12 course sessions. For further information please consult the Examination Rules §10.

Academic Integrity: The Hertie School is committed to the standards of good academic and ethical conduct. Any violation of these standards shall be subject to disciplinary action. Plagiarism, deceitful actions as well as free-riding in group work are not tolerated. See Examination Rules §16 and the Hertie Plagiarism Policy.

Compensation for Disadvantages: If a student furnishes evidence that he or she is not able to take an examination as required in whole or in part due to disability or permanent illness, the Examination Committee may upon written request approve learning accommodation(s). In this respect, the submission of adequate certificates may be required. See Examination Rules §14.

Extenuating circumstances: An extension can be granted due to extenuating circumstances (i.e., for reasons like illness, personal loss or hardship, or caring duties). In such cases, please contact the course instructors and the Examination Office *in advance* of the deadline.

4. General Readings

- Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., Lacoste, A., Sankaran, K., Ross, A. S., Milojevic- Dupont, N., Jaques, N., Waldman-Brown, A., Luccioni, A., Maharaj, T., Sherwin, E. D., Mukkavilli, S. K., Kording, K. P., Gomes, C., Ng, A. Y., Hassabis, D., Platt, J. C., Creutzig, F., Chayes, J., and Bengio, Y. (2019). Tackling climate change with machine learning. arXiv:1906.05433.
- Kaack, L. H., Donti, P. L., Strubell, E., and Rolnick, D. (2020). Artificial Intelligence and Climate Change Opportunities, considerations, and policy levers to align AI with climate change goals. E-Paper. Available at https://eu.boell.org/en/2020/12/03/artificial-intelligence-and-climate-change.

5. Session Overview

Session	Session Date	Session Title
1	10.09.2021	Introduction to climate change mitigation and adaptation
2	17.09.2021	Introduction to AI and ML
3	24.09.2021	Data gathering: Remote sensing

4	**01.10.2021**	**Data gathering: Text as data**
5	**08.10.2021**	**System optimization and control: Building energy**
6	**15.10.2021**	**Forecasting: Flood predictions**
Mid-term Exam Week: 18 – 22.10.2021 – no class		
7	**29.10.2021**	**Other AI approaches to address climate change**
8	**05.11.2021**	**Research, development & demonstration, and climate action**
9	**12.11.2021**	**Compute-relate energy consumption of AI**
10	**19.11.2021**	**System perspective**
11	**26.11.2021**	**"Parliamentary session" (student presentations)**
12	**03.12.2021**	**Guest lecture**
Final Exam Week: 13 – 17.12.2021 – no class		

6. Course Sessions and Readings

All readings will be accessible on the Moodle course site before semester start. In the case that there is a change in readings, students will be notified by email.

Required readings are to be read and analysed thoroughly. Technical aspects can be skimmed if they require background in machine learning but you should attempt to understand what they are used for. Optional readings are intended to broaden your knowledge in the respective area and it is highly recommended to at least skim them.

Session 1: Introduction to climate change mitigation and adaptation	
Learning Objective	This session provides an introduction to the course and background on climate change mitigation and adaptation. By understanding the broader picture of problems related to climate change and relevant policy considerations, this session will frame what are the opportunities and limitations of AI in this context.
Required Readings	• Filling out a questionnaire • IPCC. Global warming of 1.5 C. An IPCC special report on the impacts of global warming of 1.5 C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, Y. Chen, S. Connors, M. Gomis, E. Lonnoy, J. B. R. Matthews, W. Moufouma-Okia, C. Péan, R. Pidcock, N. Reay, M. Tignor, T. Waterfield, X. Zhou (eds.)]. 2018. https://www.ipcc.ch/sr15/chapter/spm/ **(Summary for Policy Makers)**

Optional Readings	• Gomes, C., Dietterich, T., Barrett, C., Conrad, J., Dilkina, B., Ermon, S., Fang, F., Farnsworth, A., Fern, A., Fern, X. and Fink, D., 2019. Computational sustainability: Computing for a better world and a sustainable future. Communications of the ACM, 62(9), pp.56-65. https://dl.acm.org/doi/pdf/10.1145/3339399

Session 2: Introduction to AI and ML	
Learning Objective	This session will provide an overview of the most important concepts of AI and ML and it will will lay the groundwork for the following five sessions, where we will dive deeper into different case studies using ML for addressing climate change.
Required Readings	• Independent High-Level Expert Group on Artificial Intelligence Set up by the European Commission (2019): A definition of AI: Main Capabilities and Disciplines, Brussels April 2019. https://ec.europa.eu/digital-single-market/en/news/definition-artificial-intelligence-main-capabilities-and-scientific-disciplines • Jordan, M. I. (2019). Artificial Intelligence—The Revolution Hasn't Happened Yet. Harvard Data Science Review, 1(1). https://doi.org/10.1162/99608f92.f06c6e61 • Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., et al. (2019). Tackling climate change with machine learning. arXiv:1906.05433. **(only introduction and conclusion)** • Kaack, L. H., Donti, P. L., Strubell, E., and Rolnick, D. (2020). Artificial Intelligence and Climate Change Opportunities, considerations, and policy levers to align AI with climate change goals. E-Paper. https://eu.boell.org/en/2020/12/03/artificial-intelligence-and-climate-change.
Optional Readings	• The Royal Society (2020). Digital technology and the planet: Harnessing computing to achieve net zero. Technical report, The Royal Society.
Session 3: Data gathering: Remote sensing	
Learning Objective	AI can help to gather data from sources that were previously unused, such as satellite images, for policy design, monitoring, and enforcement. This session will dive into the field of remote sensing by discussing the example of using ML to build a database of solar PV installations, and also cover other remote sensing applications in the climate context. Students will become familiar with climate-relevant concepts such as distributed renewable energy generation, nature-based solutions, and impacts on agriculture. They will learn basic concepts of computer vision and remote sensing, and discuss possible societal implications of such approaches.
Required Readings	• Yu, J., Wang, Z., Majumdar, A. and Rajagopal, R., 2018. DeepSolar: A machine learning framework to efficiently construct a solar deployment database in the United States. *Joule*, *2*(12), pp.2605-2617. https://www.sciencedirect.com/science/article/pii/S2542435118305701 • Finer, M., Novoa, S., Weisse, M.J., Petersen, R., Mascaro, J., Souto, T., Stearns, F. and Martinez, R.G., 2018. Combating deforestation: From

	satellite to intervention. Science, 360(6395), pp.1303-1305. https://science.sciencemag.org/content/360/6395/1303
Optional Readings	• Kerner, H., Tseng, G., Becker-Reshef, I., Nakalembe, C., Barker, B., Munshell, B., Paliyam, M. and Hosseini, M., 2020. Rapid Response Crop Maps in Data Sparse Regions. arXiv preprint arXiv:2006.16866.

Session 4: Data gathering: Text as data	
Learning Objective	This session will dive into text as data approaches using ML as they are relevant for climate policy across governmental and corporate reporting. Students will learn about different approaches to analyze those at scale using natural language processing (NLP) techniques. In class, we will discuss the opportunities that NLP provides for climate policy research, and critically reflect on ideas based on NLP and ML.
Required Readings	• Friederich, David, Lynn H. Kaack, Alexandra Luccioni, and Bjarne Steffen. "Automated Identification of Climate Risk Disclosures in Annual Corporate Reports." Tackling Climate Change with Machine Learning workshop, 38th International Conference on Machine Learning. 2021. • Bennett, J., Rachunok, B., Flage, R. and Nateghi, R., 2021. Mapping climate discourse to climate opinion: An approach for augmenting surveys with social media to enhance understandings of climate opinion in the United States. PloS one, 16(1), p.e0245319. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0245319#sec002
Optional Readings	• Kakia Chatsiou and Slava Jankin Mikhaylov, "Deep Learning for Political Science" in *The SAGE Handbook of Research Methods in Political Science and International Relations* (eds. Luigi Curini and Robert Franzese), SAGE, 2020. Pre-print version http://arxiv.org/abs/2005.06540

Session 5: System optimization and control: Building energy	
Learning Objective	ML techniques can help to optimize engineering systems, and reduce the energy consumed in those systems. In this lecture, students will dive deeper into the example of building energy consumption and what role ML can play to decarbonize the sector. Students will be introduced to further techniques of ML, such as reinforcement learning. We will also discuss challenges around such approaches, for example relating to behavior, cybersecurity, and misaligned incentives.
Required Readings	• Jin, X., Baker, K., Christensen, D. and Isley, S., 2017. Foresee: A user-centric home energy management system for energy efficiency and demand response. Applied Energy, 205, pp.1583-1595. • Morrison, S., 2021. How your power company can remotely control your smart thermostat: A heat wave in Texas is leading to some unexpected changes in AC settings. Vox https://www.vox.com/recode/22543678/smart-thermostat-air-conditioner-texas-heatwave

	• Gamble, C. and Gao, J., 2018. Safety-first AI for autonomous data centre cooling and industrial control. Available at: https://deepmind.com/blog/article/safety-first-ai-autonomous-data-centre-cooling-and-industrial-control
Optional Readings	• Drgoňa, J., Picard, D., Kvasnica, M. and Helsen, L., 2018. Approximate model predictive building control via machine learning. Applied Energy, 218, pp.199-216.

Session 6: Forecasting: Flood predictions	
Learning Objective	ML techniques can yield great performance increases in some forecasting tasks, which can improve a number of mitigation and adaptation approaches. In this lecture we take a closer look at flood forecasting, which helps to better respond to extreme events aggravated by a changing climate. Students will hear about forecasting techniques, and learn where ML is more and where less suitable. Using this example of flood forecasting, we will also discuss digital governance challenges.
Required Readings	• Two blog posts by Google: 1) A big step for flood forecasts in India and Bangladesh https://blog.google/technology/ai/flood-forecasts-india-bangladesh/ 2) The Technology Behind our Recent Improvements in Flood Forecasting https://ai.googleblog.com/2020/09/the-technology-behind-our-recent.html • wa Maina, C., 2020, Using IoT and Machine Learning to Help Protect Kenya's Rivers http://ciirawamaina.com/blog/2020-06-06-post.html • Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., et al. (2019). Tackling climate change with machine learning. arXiv:1906.05433. **(only Chapter 8 (Climate Prediction) and Chapter 9 (Societal Impacts))**
Optional Readings	• Lavers, D.A., Harrigan, S., Andersson, E., Richardson, D.S., Prudhomme, C. and Pappenberger, F., 2019. A vision for improving global flood forecasting. Environmental Research Letters, 14(12), p.121002. https://iopscience.iop.org/article/10.1088/1748-9326/ab52b2/meta

Mid-term Exam Week: 18 – 22.10.2021 – no class

Session 7: Other AI approaches to address climate change	
Learning Objective	There are many more ways ML can be leveraged for tackling climate change. In this session, we will cover approaches in predictive maintenance, accelerated science, and fast approximate simulations, and learn how they are used in climate-relevant domains.
Required Readings	• Reichstein, M., Camps-Valls, G., Stevens, B., Jung, M., Denzler, J. and Carvalhais, N., 2019. Deep learning and process

	understanding for data-driven Earth system science. Nature, 566(7743), pp.195-204. https://www.nature.com/articles/s41586-019-0912-1 • Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., et al. (2019). Tackling climate change with machine learning. arXiv:1906.05433. **(only Chapter 2 (Electricity Systems) and Chapter 5 (Industry))**
Optional Readings	• Attia, P.M., Grover, A., Jin, N., Severson, K.A., Markov, T.M., Liao, Y.H., Chen, M.H., Cheong, B., Perkins, N., Yang, Z. and Herring, P.K., 2020. Closed-loop optimization of fast-charging protocols for batteries with machine learning. Nature, 578(7795), pp.397-402.

Session 8: Research, development & demonstration, and climate action	
Learning Objective	When does a proposed AI application actually have impact? Here we will discuss topics around impact assessment, distinguishing hype from reality, and deployment in the real world. We will focus on the full deployment pipeline, what are potential barriers, and how the public and private sectors can foster responsible deployment at scale.
Required Readings	• Kerner, H., 2020, Too many AI researchers think real-world problems are not relevant, MIT Tech Review https://www.technologyreview.com/2020/08/18/1007196/ai-research-machine-learning-applications-problems-opinion/ • Toews, R., 2021, These Are The Startups Applying AI To Tackle Climate Change, Forbes https://www.forbes.com/sites/robtoews/2021/06/20/these-are-the-startups-applying-ai-to-tackle-climate-change/?sh=4d78c7737b26
Optional Readings	• Capgemini. Climate AI: How artificial intelligence can power your climate action strategy, 2020. https://www.capgemini.com/research/climate-ai/.

Session 9: Compute-relate energy consumption of AI	
Learning Objective	AI models are computer algorithms and therefore require computational energy. The energy consumption and greenhouse gas emissions of developing some of the largest AI models can be very high, which has led to considerable attention from the public and from policy makers. In this session, we will cover how to estimate the energy consumption from developing, training and using AI models, and discuss potential policies relating to this issue.
Required Readings	• Schwartz, R., Dodge, J., Smith, N.A. and Etzioni, O., 2019. Green AI. arXiv preprint arXiv:1907.10597 • Strubell, E., Ganesh, A., and McCallum, A. (2019). Energy and policy considerations for deep learning in NLP. In Proceedings of the 57th Annual Meeting of the Association for Computational

	Linguistics, pages 3645–3650, Florence, Italy. Association for Computational Linguistics. • Masanet, E., Shehabi, A., Lei, N., Smith, S. and Koomey, J., 2020. Recalibrating global data center energy-use estimates. Science, 367(6481), pp.984-986. • Emily M. Bender, Timnit Gebru, Angelina McMillan-Major, and Shmargaret Shmitchell. On the dangers of stochastic parrots: Can language models be too big? In FAccT, 2021.
Optional Readings	• Kamiya, G. and Kvarnström, O. (2019). Data centres and energy–from global headlines to local headaches. International Energy Agency https://www.iea. org/commentaries/data-centres-and-energy-from-global-headlines- to-local-headaches. • Simonite, T., 2021, What Really Happened When Google Ousted Timnit Gebru, Wired https://www.wired.com/story/google-timnit-gebru-ai-what-really-happened/

Session 10: System perspective	
Learning Objective	There are considerable technological, economic, and social effects of AI, and many of those have direct and indirect implications for climate change mitigation and adaptation. In this session, we will cover how some AI technologies can increase emissions through their application, and how to assess AI through a climate-focused lens.
Required Readings	• Donaghy, T., Henderson, C., and Jardim, E., 2020, Oil in the Cloud: How Tech Companies are Helping Big Oil Profit from Climate Destruction, Greenpeace Reports • Dauvergne, P., 2020. Is artificial intelligence greening global supply chains? Exposing the political economy of environmental costs. Review of International Political Economy, pp.1-23.
Optional Readings	• Wadud, Z., MacKenzie, D. and Leiby, P., 2016. Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. Transportation Research Part A: Policy and Practice, 86, pp.1-18.

Session 11: "Parliamentary session" (student presentations)

Session 12: Guest lecture	
Learning Objective	For this session, we will be joined by a guest instructor. The topic is to be announced.
Required Readings	Readings will be announced.
Optional Readings	Readings will be announced.

Final Exam Week: 13 – 17.12.2021 – no class