Engineering Tripos Part IIB, 4M22: Climite Change Mitigation, 2026-27

Module Leader

Prof. J.M. Allwood [1]

Lecturer

Prof J.M. Allwood

Lecturer

Prof A Gonzalez Cabrera Honorio Serrenho [2]

Timing and Structure

Michaelmas term. 14 lectures. Assessment: 100% coursework

Prerequisites

None

Aims

The aims of the course are to:

- inspire students to engage with the reality of implementing meaningful climate change mitigation and to equip them with skills to help us achieve more rapid progress.

Objectives

As specific objectives, by the end of the course students should be able to:

- Give an overview of the scientific and political imperatives for action to mitigate climate change.
- Assess the likely scale of impact of mitigation options, by analysing their technical potential and rates of deployment within the whole system of global emissions.
- Apply frameworks of understanding to anticipate and evaluate likely barriers to the implementation of mitigation options and to propose means to overcome them.
- Present an assessment of a mitigation option, giving clear and evidence-based analysis of scale and challenges to implementation.

Content

(the word “Outcome” in the descriptions below should be read as “By the end of this lecture, students should be able to…”)

Part I: Background and context

1: The physical system of greenhouse gas emissions

Outcome: describe several consistent decompositions of global and national greenhouse gas emissions in order to place specific proposals for mitigation in a global context.

By the end of this session, you should be able to:

- Understand the motivation for the course, its structure and assessment
- Describe a very brief summary of the current scientific consensus on global warming
- Explain four different decompositions of emissions statistics

2: The political context of climate mitigation

Outcome: describe the context of climate mitigation with reference to key international treaties and discuss the urgency and scale of change recommended by climate science.

Learning objectives:

- Understanding mitigation targets
- The structure of international governance on mitigation
- The structure of UK governance on mitigation

Part II: Physical options for mitigation

3. Supply-side options for mitigation: energy sources and conversion

Outcome: describe the main technical options for low carbon energy supply and efficient energy conversion and discuss their technical potential and rate of deployment.

The learning objectives of this session are:

- Overview of the global energy system from supply to final use, and trends in global and UK use
- Options or energy supply – conventional
- Options or energy supply – renewable

4. Supply-side options for mitigation: intermittency, new technologies, Absolute Zero

Outcome: describe the main technical options for low carbon energy supply and efficient energy conversion and discuss their technical potential and rate of deployment.

By the end of this session, you should:

- be able to describe the problem of Intermittency and discuss our options to deal with it
- be able to describe the main new technologies for emissions capture or removal and energy transfer
- be aware of the "Absolute Zero" analysis which explores the delivery of zero emissions by 2050 with today's technologies.

5. Demand-side options for mitigation: energy efficiency; transport

Outcome: describe the services by which humans benefit from using energy, suggest how these services can be delivered differently and discuss the determinants of preference for alternative forms of service delivery.

By the end of this session, you should be able to:

- Analyse the potential for efficiency in other passive systems (using the references provided) and compare the to the potential for device efficiency
- Discuss the way that “efficiency” may be visible or invisible to users, and describe the forms of trade-off required to deliver step changes in total energy demand
- Have a basis for exploring the de-carbonisation of other forms of transport.

6. Demand-side options for mitigation: buildings and AFOLU

Outcome: describe the services by which humans benefit from using energy, suggest how these services can be delivered differently and discuss the determinants of preference for alternative forms of service delivery.

By the end of the session you should be able to:

- Discuss the constraints on the total global biomass harvest that limit the future potential of bio-energy
- Provide and overview of the options for improving the energy efficiency of buildings

7. Demand-side options for mitigation: industry and process emissions

Outcome: describe the major human uses of industrial materials and natural biomass and discuss options for reducing the emissions associated with its delivery.

By the end of this session you should be able to:

- Describe the main sources of industrial emissions and explain why energy efficiency has only limited remaining mitigation potential
- Describe the technical options for implementing material efficiency and give examples of each

8. Group tutorials 1 (sign up on Moodle)

In advance of the tutorial, students will (a) prepare a first draft of their assessment poster (based on a template given out in advance) in which they describe the physical mitigation option they are proposing and (b) discuss and challenge similar drafts prepared by each other student in the group. In groups of 6-8, and facilitated by experienced full-time researchers in this area, students will then:

- *reflect on the mitigation potential of their proposed mitigation option and discuss and contrast the means they have used to evaluate it*
- *discuss the physical implications and constraints of their implementation and challenge each other’s assumptions.*

9. Prioritisation: choosing between mitigation options across final services

Outcome: choose appropriate tools that can be used to evaluate mitigation options and apply them to determine the relative merits and limitations of specific options

In this lecture we will:

- Identify criteria to prioritise mitigation options;
- Reflect on the impact of the choice of system boundaries and the problems of double counting on the validity of claims of potential for mitigation;
- Recognise the relative merits and limitation of the choice of various metrics to prioritise mitigation options.

10. Physical constraints: limits and deployment rates

Outcome: Describe the constraints on rates of different mitigation options

By the end of this session you should be able to:

- Anticipate likely constraints on the deployment rates of any technological or societal transformation of the scale required to mitigate climate change
- Think about mitigation as a societal process – not just a new mousetrap – and engage in much wider discussions
- Anticipate eagerly the remainder of the course!

Part III: Barriers to implementation and overcoming them

11. Stakeholders, decision analysis and co-operation

Outcome: describe the main players involved in supporting and opposing implementation and provide a structured analysis of a mitigation opportunity by showing how design choices determine key performance metrics that are traded off against each other

By the end of today's session, you should be able to:

- Describe the main players involved in supporting and opposing implementation
- Provide a structured analysis of a mitigation opportunity based on the framework of game theory, in order to describe how competing incentives determine how to choose a path to implementation
- Discuss two case studies of how the game-theory framework reveals the path to implementation of two mitigation options in practice.

12. Implementation by businesses

Outcome: describe the basis by which businesses choose to invest in new assets, products or markets and discuss the development of a new offering from first trial through to widespread adoption

By the end of this session you should be able to:

- Discuss the responsibilities of corporate directors, according to the UK's Companies Act
- Explore how the goal of climate mitigation relates to the goal of "maximising shareholder value"
- Describe a process for revealing entrepreneurial opportunity for businesses seeking to profit in zero emissions.

13. Implementation by Government

Outcome: discuss some determinants of political acceptability and describe how these influence policy implementation at national and international scale, contrasted between developing and developed countries; discuss the use of tax, spending, regulation, targets and information options in climate mitigation to date and critically evaluate options to influence the adoption of proposed future mitigation strategies.

By the end of this session you should be able to:

- Have an overview of the political processes of the UK
- Discuss the main forms of political intervention that have been tried to date to support climate mitigation.
- Reflect on the intimate real-world experience of Lord Wilson.

14. Implementation by individuals

Outcome: discuss how individuals make the choices that determine their energy requirements and that exert influence

By the end of this session you should be able to:

- Describe three contrasting frameworks of understanding individual preferences
- Describe several ways to characterize human aspiration
- Reflect on a set of models of how individuals make decisions

15. Breaking out of lock-in: wiggle-room, agendas and influence; Action and inaction: where we are today and case studies of optimism

Outcome: describe and discuss wider opportunities to escape the lock-in of established choice between businesses, governments and households; summarise the world and UK response to climate change to date, discuss the relative lack of progress and propose ideas for more rapid progress

By the end of today's session you should be able to:

- Review where we're at as a world (and recent UK announcement)
- Describe some positive case studies
- Review what we've seen on implementation as a basis for planning the implementation component of your essay

16. Group tutorials 2 (sign up via Moodle)

Using a similar format to the first set of group tutorials, students should in advance of the tutorial prepare a bullet-point outline of their individual essay, focusing particularly on the implementation strategy. During the session, and facilitated by experienced tutors, they will:

- *Discuss and challenge their anticipation of the barriers to implementing their proposed mitigation strategy, in business, government and households*
- *Review and brainstorm the options to break lock-in.*

Assessment

The aim of this course is to provide students with a practical overview of the physical options for mitigating climate change combined with insights into the difficulty of implementation and opportunities to overcome the difficulty. We have therefore designed the assessment, which is all coursework, to give students the experience of working through this reality: each student will select a mitigation option, and then apply the learning of the course to assessing how it can be brought into practice.

Mitigation option: by the end of the first seven lectures, each student should specify a mitigating action as the basis for their coursework. This action should be described as a physical change in the form of "instead of A which happens at present, B will happen leading to a reduction in UK emissions." This change should be an additional contribution to mitigation in the UK, beyond what is already planned. It should be specific and be based on what physically changes (i.e. "Instead of today's average speeds of 100-150 mph, all high-speed trains in the UK will travel with a maximum speed of 75mph to reduce their energy consumption by 30%") not on the incentive provided for change ("the UK will have a carbon tax of £300/tonne of CO2") or on an aspiration for a voluntary behaviour change ("people will eat less meat"). The option should within 10 years be operating at a scale that will lead to a permanent net reduction in UK annual emissions by 1 MtCO2e/yr (this is around 0.2% of today's total). The phrase "net reduction" indicates that if implementing the option requires additional emissions, for example in construction, then the option should lead to savings that "pay off" these additional emissions, and then delivers savings of 1MtCO2e/yr.

The assessment has three components:

Poster: Mid-course, students will submit an A3 poster using this template [3] that:

- Describes the physical changes required by their proposed mitigation option including a time-line with one or more pathways to full implementation within 10 years.
- Provides detailed calculations to justify the predicted net reduction in UK emissions
- Anticipates the second half of the course by describing all the actors who will either support or object to the option and explaining their motivation.

Poster reviews: Each student will write a short peer-review (of no more than 150 words per review) of three other posters (we will allocate reviewers randomly to each poster). The peer-reviews will be marked based on the insightfulness of their suggestions about each poster. To what extent does the review help the author of the poster improve their work? Good reviews will make specific suggestions.

Essay: At the end of the course, students will submit an individual essay of no more than 2000 words (any words in tables or appendices are *included*within this limit, but reference citations are *excluded,* and please do not waste words on an abstract or executive summary) providing a complete assessment of their proposal, using appropriate graphics and references to support their case. The essays will be assessed based on:

- the physical reality of the recommended option: does the essay contain convincing evidence that the option will lead to a net reduction in UK emissions of 1 $MtCO_{2e}$/yr within 10 years?
- Cost analysis: who will incur what additional costs as the option is implemented? Why will they choose to pay? If there are no additional costs, why hasn't the option been implemented already, and what will happen to bring it about now?
- Actors: it is unlikely that the government will micro-manage every mitigation action, so who will lead delivery of implementation, how and why?
- Marks will not be awarded for presentation, but to make your essay easy to read, please avoid use of Acronyms unless they are widely known to the public, and use single column layout. Marks will be deducted if it is not possible to trace the argument back to evidence.

From 2025 onwards – completing 4M22 now that AI is a reality:

- You are free to make use of ChatGPT or other similar software in completing your assignments for this course, if you wish to do so. However, you remain responsible for every aspect of the content of the course. AI is artificial as it cannot tell the difference between truth and fiction – so if your essay includes material that is obviously made up (for example if you use made-up references), you will fail.
- ChatGPT and similar takes most of its input from journalists, blogs and corporate websites which are easy to find – but do not use verified evidence. In contrast, your work must be based on trusted evidence. To illustrate this (1) please divide your references into three groups: (a) peer-reviewed high quality academic papers; (b) government data sources; (c) other – which markers will assume are untrustworthy. Please include hyperlinks to all referenced material, so markers can verify them.
- The quality of academic journals varies widely, and you should limit yourself to those in the Q1 (top quartile) category of this list [4]. .
- Use peer-reviewed references solely to introduce new primary evidence into your essay. ("Primary" means that the source you are quoting has gathered it for the first time, explaining the methodology they used, so it can be verified.) Do not tag citations to the end of sentences in the hope it gives your work authenticity. Instead, reference academic work by author name, using the name as the subject of a verb to explain the originality of the evidence. E.g. "Cullen et al. (2012) present a global analysis of the transformation of steel from liquid production to final products, with all data triangulated to at least two data sources."
- Your essay must include original analysis by you, not by AI, of government data, to support your claims to mitigation. Typically, this will involve data on recent demand for the activity you are discussing and analysis of emissions. Some good starting points are UK emissions statistics [5], Government emissions factors [6], the Digest of UK Energy Statistics [7], UK Trade data [8].

Please note the Department's guidelines on the use of images in coursework: https://libguides.cam.ac.uk/copyright/students/images [9].

The **marks** for the course will be allocated as:

- Mid-term poster (20%)
- Peer-reviews of three other posters (10%)
- Individual essay (70%)

Important: For all MEng students, all coursework must be submitted anonymously using your candidate number and not a name. For Graduates whatever course you are doing, you MUST submit your coursework with your crsid, forename and surname– otherwise, we cannot trace it back to you. Following difficult experiences last year, we regret that we will not mark any submitted coursework that does not meet these requirements.

Coursework	**Format**
Coursework activity #1 **A3 poster**	Individual Non-anon
Coursework activity #2 Peer-review reports on three other posters	Individual Anonymo
Coursework activity #3 Individual essay	Individual Anonymo

Further notes

Tutorial support

A week ahead of each of the group tutorials we will release a scheduling app on the Moodle site, to ask you to sign up to a tutorial at a particular time. The first tutorial is to help you prepare your poster and the second to help you prepare your essay. During the one-hour tutorial, you will have the chance to discuss your ideas about the assessment with a small group (of 8-10 students) and a tutor. The course tutors are all members of my research group, who have several years of experience thinking about the issues raised in the course.

Learning strategy

We're addressing a broad agenda in this course – deliberately stretching the boundaries of engineering, because that's the only sensible way to approach the goal of real mitigation. To get the most out of the course:

- **Learn by doing**: choose the mitigation option you're going to focus on in your final essay as early as you can so that you are always testing what you hear in the sessions against your own needs for your own essay
- **Stay active**: scribble notes while watching the videos, and follow up on reading that catches your interest.
- **Stretch yourself**: dig into the topic, around the areas of your own interest – I'll provide pointers, but you can search the academic or government literature yourself, find out what industry bodies are saying, look for good journalists etc.
- **Interact**: make use of the group tutorials and poster-session to get as much feedback as you can about the credibility of your proposal – and test your ability to probe reality as your review and comment

(constructively!) on other students' emerging proposals. Use the Open Forum on the moodle site to interact with each other and support each other's learning.

Booklists

Specific reading is offered for each lecture in this course, uploaded to the Moodle site, along with the lecture handouts and lecture videos.

Examination Guidelines

Please refer to Form & conduct of the examinations [10].

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Links
[1] mailto:allwood-office@eng.cam.ac.uk
[2] mailto:ag806@cam.ac.uk
[3] https://www.vle.cam.ac.uk/pluginfile.php/18415541/mod_book/chapter/566781/4M22%20Poster%20Template%202020.pptx
[4] https://www.scimagojr.com/journalrank.php
[5] https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-statistics-1990-to-2023
[6] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2025
[7] https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes
[8] https://www.uktradeinfo.com/trade-data
[9] https://libguides.cam.ac.uk/copyright/students/images
[10] https://teaching26-27.eng.cam.ac.uk/content/form-conduct-examinations