FFR170 Sustainable Energy Futures 2019
Course PM

1 Course management

7.5 credits, study period 1, autumn 2019
Department: Space, Earth and Environment, Division of Physical Resource Theory
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2 General information

The course is part of the Master's programs Sustainable Energy Systems, Nuclear Engineering and Industrial Ecology at Chalmers University of Technology. The course is taught in English. The course consists of:

- lectures,
- calculations, and
- student debates.

3 Admission and prerequisites

The students are required to have documented calculating skills and at least 7.5 credits worth of courses in sustainable development or environmental science.

4 Aim of the course

The course aims to give students knowledge of the general development of the energy system (past development and outlook for the future), its environmental and resource impacts, as well as tools to analyze these developments. The overall aim of this course is to address the following questions:

- What role may energy efficiency, renewables, fossil fuel and nuclear power, play in the near- and long-term future if the climate challenge is to be met?
- In which sectors are limited energy resources most efficiently used, e.g., should biomass be used for transportation fuels or for heat production?
- Which climate policies are needed for a cost-effective solution to the climate challenge?
- How may climate change policies reshape the world energy system over the next century?

The aim is to illustrate these issues by drawing upon recent research in the area, and based upon this to discuss visions for a sustainable energy future.

5 Content

- **Systems analysis** - system boundaries, scale, space & time, emission allocation problems, net energy analysis, marginal vs average electricity
- **Energy economics** - cost efficiency, discounting, investment analysis, prices vs costs, supply & demand curves, external costs, opportunity costs
- **Climate science and emission trends** - current and historic emissions, climate sensitivity and its uncertainty, implications for future emission reductions, burden sharing between developed and developing countries
- **Policy instruments** - carbon taxes vs cap-and-trade schemes, direct support vs technology neutral policies, and other instruments
- **Energy efficiency** - end-use efficiency, price elasticity of demand, the energy efficiency gap, rebound effects
- **Fossil fuels** - history of fossil fuel use, future availability, peak oil, shale gas and other new technologies
- **Carbon capture and storage** - capture processes (post-combustion, precombustion, oxyfuels), transport and storage options, leakage risk, costs
- **Nuclear power** - nuclear physics and fuel cycles, basic light water reactor design, safety, waste management, link to nuclear weapons, nuclear power in the global energy system
- **Intermittent renewables** - grid integration of solar and wind power, global potential, recent growth and cost development, solar heating and cooling, solar fuels

- **Bioenergy** - biofuel production, land use and implications for food production, emissions from direct and indirect land use change
- **Other topics** - power grids, energy use in the transport sector, batteries, fuel cells and hydrogen, energy in the developing world, international climate politics

6 Learning outcomes

At the end of the course, students should be able to:

- apply the concepts and tools presented in the course (see below under Content) to analyze real-world problems related to energy systems.
- understand the difference between marginal and average electricity, and apply this knowledge to solve the problems in specific contexts.
- describe how climate policy instruments such as a cap-and-trade scheme or a carbon tax work, and reflect upon advantages and disadvantages compared to other policy instruments.
- explain the concept of climate sensitivity and what implications the uncertainty in this parameter will have on the temperature impacts of our emissions, and how much we need to reduce emissions if we want to meet the below 2-degree target of the Paris agreement.
- discuss the significance of climate negotiations such as the Paris Agreement, and whether they are sufficient to meet the climate target(s).
- understand the complexity of controversial energy technologies such as carbon capture and storage, bioenergy or nuclear power, and to present the major arguments of both sides.
- explain why energy efficiency measures are often not implemented, even though they may be more economically attractive.
- explain what options grid operators have for dealing with large amounts of variable renewable electricity sources like solar or wind power.
- calculate the levelized cost of electricity, given fuel costs, operation & maintenance costs, and investment costs and discuss the pros and cons of using it to evaluate a technology.
- calculate how much uranium is required to operate a nuclear reactor for a year, and how much plutonium is produced.

- make appropriate assumptions when available information on a problem of the above type is incomplete.
- perform back-of-envelope calculations to make rough ”sanity checks” of energy systems questions. For example: if a family installs solar cells on the roof of their house, would the modules provide enough electricity (on average) to power their electric car?
- distinguish facts from values. Discuss Hume's Law (one cannot derive an "ought" from an "is") when doing energy analysis. Discuss what to do about environmental problems related to energy use.
- discuss the responsibility of individuals versus governments when it comes to solving the climate problem.

7 Course literature

- The list of reading materials in the course compendium
- Makten över klimatet (Swedish) / Solving the Climate Challenge (English) by Christian Azar.

The the English version of Christian Azar's book are available at Cremona. The Swedish version can be found in online book stores.

Reading assignments are an important part of the class materials, as they provide students with the depth and the knowledge you need to think critically and conduct well informed analyses. There is only so much information we can teach during the lectures. Students are expected to learn the rest of the materials independently through reading materials, class discussions, debates, and do additional research to prepare for the debates. The reading materials will deepen your knowledge, broaden your views, strengthen your analytical skills and help you understand the pros and cons of different methods/views with depths and theoretically underpinning. Students are expected to read the required readings. The key concepts from the reading materials are integrated with the problem sets and debate topics. Readings help students observe similar (or new) insights independently, improve your understanding of the calculation exercises and become sharper in your debates. Some questions in the exams will be selected from the assigned readings.

8 Examination and grading

In order to pass the course, you must:

- submit all calculation exercises and participate in the discussion (18%)
- participate as audience in all but one of the student debates (12%)
- participate as a debate member in one of the student debates (10 or 12%)
- pass the written exam (60%).

The students are required to upload your calculations onto the course's Canvas website before the due dates. The calculation exercises are due on Tuesday noon. These submissions won't be graded based on how well you do but you must try to complete all calculations and show your work for each question. The TAs will review the submissions to help them guide the discussion during the exercise sessions. This part of the grade will be 0/3, i.e., each calculation exercise will be 3 points if a homework is submitted otherwise a 0 point will be given. If a student submits all the calculation exercises on time, then he/she will receive 18 points (6×3 pt). It is important for you to submit your homework on time as points will be deducted from a late submission unless a student communicates with the TA beforehand. For discussion questions, write down two or three short sentences about your key arguments. The solutions for each calculation assignment will be uploaded on Wednesday noon.

Attending the calculation exercises is optional but strongly encouraged.

All students must participate in all four debates as audience in three and as debate members in one. You will choose your debate topic at the beginning of the class. Your position (*for* or *against* a topic), however, will only be announced two weeks prior to the debate. Students will receive 12 points (3×4 pt) from participating the debates as audience. Students will receive 10 points from participating a debate, and 2 extra points from winning the debates (see the *Debate* sheet for more information). If a student misses a debate, he/she must turn in a 500-word write-up stating his/her position of the debate topic and explain why.

The rest of the grade (60%) will be based on the written exam. A student must score at least 24pt (out of 60pt) in the final exam in order to pass the course. The final grade is the sum of the final exam, homework and the debate.

The final grade of the course corresponds to the following total points:

$<$ 64 pt Fail; 64 pt – 75 pt Grade 3; 76 pt – 87 pt Grade 4; $\geq$ 88 pt Grade 5

9 Group assignments

For issues regarding course administration, contact Yuan Liao (yuan.liao@chalmers.se, 073 570 43 23). If you need study assistance, please try to solve the problem by discussing with your fellow students before contacting your teaching assistant. The calculation exercises and debates are divided into four groups.

- Group 1 Yuan Liao yuan.liao@chalmers.se
- Group 2 Daniel Pitulia daniel.pitulia@chalmers.se
- Group 3 Xiaoming Kan kanx@chalmers.se
- Group 4 Ahmet Mandev mandev@chalmers.se

You will find us at the division of Physical Resource Theory, floor 3V of the EDIT building, one floor above Café Linsen.