ES 305 - TECHNOLOGY OF RENEWABLE ENERGIES
IES Abroad Freiburg

DESCRIPTION:
This course gives a general introduction of renewable energy technologies for non-engineers. The basic conversion technologies applied for turning different renewable energy sources into useful forms of energy are explained. Basic engineering knowledge for (thermal, mechanical, chemical) energy conversion is described where necessary, so that participants can assess the technical challenges and realistic efficiencies of such technologies. The technical problems facing the power grids when integrating fluctuating renewable energy sources are presented and discussed. Also, methods for assessing the environmental impacts of renewable energy deployment are introduced and implications of 100% energy systems are discussed. Where it is suitable, annotations to economic aspects of renewable energy technologies are made. Through the course, the students should acquire a knowledge base that helps them to better assess the discussion about massive renewable energy deployment by weighing the resulting benefits and challenges and by correctly accounting for given physical and technical limits. The course is taught by engineers who adapt the technical details to a level that is understandable for non-engineers.

CREDITS: 3 credits

CONTACT HOURS: 45 hours

LANGUAGE OF INSTRUCTION: English

PREREQUISITES: none

ADDITIONAL COST: none

METHOD OF PRESENTATION:
- Lectures
- Student presentations
- Exchange and discussion
- Application of Moodle

Additional material available on Moodle. This platform is also the place to share assignments and to follow recent developments in the field.

REQUIRED WORK AND FORM OF ASSESSMENT:
- Course participation – 10 %
- Midterm Exam – 10 %
- Written assignment – 30 %
- Final Exam – 50 %

Course Participation – 10 %
Students are expected to participate in debates with questions related to the readings and Students are required to complete all reading assignments and will be expected to demonstrate this through regularly assigned homework, pop quizzes, and/or insightful and relevant contributions to in-class discussion. All these components will count toward the class participation grade. Participation also applies to course-related trips, outings and/or special events in and around Freiburg. A rubric for participation is available in the appendix and on Moodle.

Midterm Exam – 10 %
The mid-term assessment is an in-class oral presentation connected to the written assignment mentioned above. The students present their assignments, answer further questions by the lecturer and the fellow students and discuss it in the course.

Presentations will be held during the sections that the topic belongs to, respectively.

Written Assignment – 30 %
The assignment takes the form of a review and discussion of 2–3 journal articles about one topic of the course (around ten pages); each instructor formulates a number of topics and names the research articles that should be reviewed; the student can choose her/his preferred topic.

Final Exam – 50 %
The final assessment is a written exam and tests the students' overall knowledge and ability to analyze the concepts presented during the course.

LEARNING OUTCOMES:
By the end of the course students will be able to:

- Distinguish the general forms of renewable energy and the technologies for converting the different primary sources into secondary and final energy.
- Estimate the efficiency of conversion of different types of technologies for using renewable energy.
- Calculate annual energy yields of different renewable energy sources.
- Research and analyze basic technological aspects of using renewable energy sources.
- Analyze and discuss the potential of renewable energies to contribute to satisfying the energy demand of a country.
- Compare the environmental impact of different renewable energy technologies and contrast it to fossil and nuclear energy usage.
- Evaluate the consequences of a massive use of renewable energy technologies.
- Understand possible approaches and system designs for 100% renewable energy systems for Germany.
- Critique national, European and foreign energy policy measures for support of renewable energy.
- Investigate the technical problems that fluctuating renewable energy sources pose to the electricity grids.

Attendance Policy (see also the detailed version on Moodle ESS Academics page)
IES Abroad courses are designed to utilize the unique contribution of the instructor; the lecture/discussion format is regarded as the **primary mode of instruction**. Therefore, attendance is mandatory. Any unexcused absence will incur a penalty on your final course grade. Deductions from grades due to absences are based on contact hours (= 45 minutes). Any unexcused absence will result in a penalty on your final course grade (1 unexcused contact hour absence - 1%, 2nd unexcused contact hour absence -2%, 3rd unexcused contact hour absence – 3% and so on). Any student who misses more than 25% of a course (= more than 11 contact hours), whether the absences are excused or are unexcused, will receive an "F" as the final grade in the course.
ESS courses may have entire course blocks that take place on one day in addition to longer field trips that count for several contact hours. In this case, the actual missed contact hours are added together, and the absences are sanctioned according to the rule above. If you are late for a planned field trip, you will generally not be able to join the trip, since the group needs to leave on time and cannot wait for one person. Punctuality is therefore essential here. If you miss a class, it is **your responsibility** to make up on everything that was covered in class. Tests/presentations missed during unexcused absences **cannot be made up.**
Arriving late for class: Punctuality is important for the planned course schedule. If you are late for class, the late time will be recorded and added up at the end of the course. You will receive a grade reduction based on the accumulated amount of missing contact hours (as outlined above; i.e., if you were late by 15 minutes on 3 days, your grade would be reduced by 1% for 1 missing contact hour).
LATE OR FAILURE SUBMISSION OF ASSIGNMENTS: Late submission of assignments or failure of submission of assignment results in the grade F of that particular assignment. This does not apply to late or non-submission due to illness with an excused absence.
Excused absence: Please call the IES Center before the start of your first class if you are ill and would like to be excused from your course, as outlined in the "Cell Phone and Attendance Policy" handed out during orientation. Student Affairs staff will decide whether your absence can be excused directly or whether a doctor's note is necessary. Absences due to religious observances and family emergencies may be excused at the discretion of the Center Director, with written approval. A petition for an excused absence due to

a religious holiday needs to be submitted 2 weeks in advance. If permission is granted, the student needs to inform the Academic Dean, the Student Affairs Team and their instructors. Absences due to private travel or travel delays cannot be excused, even with advanced notice.

ACADEMIC INTEGRITY CODE:
Students are expected to abide by the IES Abroad Code of Academic Integrity. The detailed IES Abroad academic integrity code can be accessed on Moodle.
All work submitted by a student for academic credit should constitute the student's own original work. Regardless of the quality of work, plagiarism will result in a failing grade for the course and/or an academic review and possible expulsion from the program. Plagiarism may be broadly defined as "copying of materials from sources, without acknowledging having done so, claiming other's ideas as one's own without proper reference to them, buying materials such as essays/exams, and using AI-generated content without disclosure."
As AI tools continue to evolve, learning how to use them responsibly is an important emerging skill. Some of our courses allow students to explore the use of generative artificial intelligence (GAI) tools such as ChatGPT for some assignments and assessments. The instructor of each course will communicate whether GAI may be used in a course and provide specific guidelines and procedures for its appropriate use.

Updated information on your course and readings, including additional readings from journalistic articles, can be found on the Moodle platform at https://moodle.iesabroad.org/login/index.php

CONTENT:

Week	Content	Assignments and Readings
Week 1	**Session 1: Overview of Renewable Energy Technology and Their Potential** This session gives a presentation of the course content followed by an overview of the different forms of renewable energy and the assessment of their theoretical, technical and economic potential. Concepts for comparing the environmental impact of different energy technologies (both conventional and renewable) are discussed. Policy measures for the support of renewable energy sources are presented and compared.	Required Readings: • Hirschberg et al, Strengths and Weaknesses, pp. 447-457.
	Session 2-3: Photovoltaics The students will gain understanding of the principle of photovoltaic energy conversion, the elements of industrial solar cells and modules as well as the production technology. Different characterization methods and optimization strategies are discussed.	Required Readings: • Goetzberger and Hoffmann, Photovoltaic solar energy generation. • Goetzberger, Knobloch and Voss, Crystalline silicon solar cells.
	Session 4-5: Biomass Energy During this session, an overview is given on the different technologies in biomass energy conversion.	Required Readings: • Khanal, Bioenergy and biofuel from biowastes and biomass.

	Detailed presentation and discussion on biogas technology with focus on bio-methane is followed by hydrothermal carbonization. Application to fertilization of exhausted soils with bio-coal is presented.	• Sevilla, Macia-Agullo and Fuertes, Chemical and structural properties of the carbonized products, pp. 3152-3159. • Steinbeiss, Gleixner and Antonietti, Effect of biochar amendment, pp. 1301-1310.
Week 2	**Session 6-8: Solar Thermal Energy Conversion and Applications** This session will introduce solar thermal energy converters. After characterization of solar collectors, the different collector designs will be discussed. Hydraulics of solar thermal systems will be introduced and recommendations for system design will be given.	Required Readings: • Peuser, Remmers and Schnauss, Solar Thermal Systems.
	Session 9-10: Energy Efficiency in Buildings Building Automation as a key tool for buildings´ energy efficiency will be introduced. Monitoring of thermal building behavior will be discussed and shown based on R&D demonstration buildings. New technology like predictive building control will be explicated.	Required Readings: • Bollin, Automation regenerativer Wärme- und Kälteversorgung von Gebäuden.
Week 3	**Session11: Wind Energy** The potential of wind energy is discussed. The students learn about statistical analysis of wind as a resource. Wind turbine types are classified, and their components are explained. Basic aspects on the control of wind turbines are discussed. Further, it is explained how the annual energy yield can be derived by wind statistics and the power curve of the wind turbine. Finally, selected topics which are important for project developments are discussed, e. g. assessment of environmental effects.	Required Readings: • Ackermann, Wind Power in Power Systems.
	Session 12: Hydro Power The potential of hydro power is discussed. The students learn about statistical analysis of the resource, namely about hydrographs. Hydro power plants are classified, and their components are explained. Further, it is explained how the annual energy yield can be derived by hydrographs and in combination with the hydro power equation. Finally, selected topics which are important for project developments are discussed, e.g. the assessment of environmental effects.	Required Readings: • Heinloth, Survey of renewable energy.

	Session 13-14: Electricity Grids, Intelligent Coordination and Energy Storage The last session discusses the technological and organizational challenges posed by the integration of larger scales of fluctuating renewable energy sources into the power grid. The resulting need for grid extensions and congestion management are evaluated, and possible solutions from the area of smart grids are presented. In addition, available technologies for energy storage are introduced and their possible applications in a sustainable energy system are discussed. Finally, the economic aspects of the given solutions are considered.	Required Readings: • Kok, Scheepers and Kamphuis, Intelligence in electricity, pp. 179-210. • Apostatoe, 1,500,000 kettles.
	Session 15: Final Exam	

COURSE-RELATED TRIPS (possible destinantions):

- Staufen (geothermal drilling)
- Freiamt (biomass and wind energy)
- St. Peter (biomass and wind energy)

REQUIRED READINGS:

- Ackermann, Thomas. Wind Power in Power Systems. Chichester, UK: John Wiley & Sons, 2005.
- Bollin, Elmar. Automation regenerativer Wärme- und Kälteversorgung von Gebäuden, Wiesbaden: Vieweg+Teubner Verlag, 2009.
- Goetzberger, A. and Hoffmann, V. Photovoltaic solar energy generation. Berlin, Heidelberg: Springer, 2005.
- Goetzberger, A., Knobloch, J. and Voss, B. Crystalline silicon solar cells. Weinheim: Wiley, 1998.
- Heinloth, K. "1 Survey of renewable energy," in The Landolt-Börnstein New Book Series. Ed. K. Heinloth. London: Springer, 2014.
- Hirschberg, S., Dones, R., Heck, T., Burgherr, P., Schenler, W. and Bauer, C. „Strengths and Weaknesses of Current Energy Chains in a Sustainable Development Perspective," in atw - International Journal for Nuclear Power, 51 (7), 2006, pp. 447-457.
- Khanal, S. K. (ed). Bioenergy and biofuel from biowastes and biomass. Reston: American Society of Civil Engineers, 2010.
- Kok, Koen, Scheepers, Martin and Kamphuis, René. "Intelligence in electricity networks for embedding renewables and distributed generation," in Intelligent Infrastructures. Eds. Rudy R. Negenborn, Zofia Lukszo and Hans Hellendoorn. London: Springer 2008, pp. 179-210.
- Peuser, Felix A., Remmers, Karl-Heinz and Schnauss, Martin. Solar Thermal Systems: Successful Planning and Construction. London: James & James Science Publishers, 2002.
- Sevilla, M., Macia-Agullo, J. A. and Fuertes, A. B. "Hydrothermal carbonization of biomass as a route for the sequestration of CO2: Chemical and structural properties of the carbonized products," in Biomass and Bioenergy, 35 (2011), pp. 3152-3159.

- Steinbeiss, S., Gleixner, G. and Antonietti, M. "Effect of biochar amendment on soil carbon balance and soil microbial activity," in Soil Biology & Biochemistry, 41 (2009), pp. 1301-1310.

Filmography

- Apostatoe: 1,500,000 kettles, http://www.youtube.com/watch?v=WCAzalhldg8: 2008.

RECOMMENDED READINGS:

- Bhattacharyya, Subhes C. Energy Economics – Concepts, Issues, Markets and Governance. London: Springer, 2011.

- Kaltschmitt, Martin, Streicher, Wolfgang and Wiese, Andreas. Erneuerbare Energien – Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Berlin, Heidelberg: Springer Vieweg, 2013.

Additional recommendations will be given during the course.

Appendix:

Rubric for course participation:

A	**Excellent participation** The student's contributions reflect an active reading of the assigned bibliography. Skillfully synthesizes the main ideas of the readings and raises questions about the applications and implications of the material. Demonstrates, through questions and comments, that they have been capable of relating the main ideas in the readings to the other information discussed in the course and with their own life experience. The student makes informed judgments about the readings and other ideas discussed in class, providing evidence and reasons. They respectfully state their reactions about other classmates' opinions and can contribute to the inquiry spiral with other questions. The student gets fully involved in the completion of the class activities.
B	**Very good participation** The student's contributions show that the assigned materials are usually read. Most of the time, the main ideas are identified, even though sometimes it seems that applications and implications of the information read were not properly reflected upon. The student can construct over others' contributions, but sometimes seems to interrupt the shared construction to go over tangents. They are respectful of others' ideas. Regularly involved in the activities but occasionally loses concentration or energy.
C	**Regular participation** The participant evidences a regular reading of the bibliography but in a superficial way. They try to construct over others' ideas, but commonly provide comments that indicate a lack of preparation about the material. Frequently, contributions are shallow or unarticulated with the discussion in hand.
F	**Insufficient participation** Consistently, the participant reads in a shallow way or does not read at all. Does not participate in an informed way and shows lack of interest in constructing over others' ideas.