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ERASMUS+
Photovoltaics Online Teaching
PV-iTeach Project
Course Catalogue

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University of Freiburg
Department of Sustainable Systems Engineering – INATECH
Georges-Koehler-Allee 10
79110 Freiburg, Germany

In cooperation with

Technical University of Denmark
Anker Engelunds Vej 1 Bygning 101A
2800 Kgs. Lyngby, Denmark

Cologne University of Applied Sciences
Cologne Institute for Renewable Energy – CIRE
Gustav-Heinemann-Ufer 54
50968 Cologne, Germany

FH Münster University of Applied Sciences
Department of Electrical Engineering and Computer Science – FHM
Hüfferstraße 27
48149 Münster, Germany

Dalarna University
Energy and Construction
Högskolegatan 2,
791 88 Falun, Sweden

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Preamble

An Overview of the PV-iTeach Program

As Europe and the rest of the world seek a green energy supply, solar photovoltaic (PV) systems are rapidly spreading and evolving to meet demand, accompanied by a commensurately growing need for skilled PV professionals. At the same time, low quality PV systems and low PV education levels persist in many countries, with significant deficiencies in practical knowledge and skills. Within this context, the big players in the solar energy education field in Europe got motivated to unite their forces and develop the PV-iTeach project idea. Within the PV-iTeach program a wide range of freely available courses from experienced and high profile institutions is offered.

Target Group

The PV-iTeach project is training pre-career and continuing education PV professionals that would otherwise be unable to obtain an in-depth PV education in the absence of PV-iTeach.

Participating Organisations

The PV-iTeach project is carried out by a consortium of five European universities: the Technical University of Denmark (DTU), the Technische Hochschule Köln in Germany (TH Köln), the Fachhochschule Münster in Germany (FH Münster), Dalarna University in Sweden (DU), and the Albert-Ludwigs-Universität Freiburg in Germany (Uni Freiburg). Each of the partner universities brings significant knowledge and experience in different but complementary aspects of photovoltaics in addition to practical experience in implementing related online learning.

Intellectual Outputs

The core educational output of PV-iTeach takes the form of online courses focusing on different PV topics that could be accessed from all over the world. Courses are derived from existing in-person courses at each of the partner universities and enhanced for an

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online setting. In order to enhance online learning outcomes, a special focus is placed on the integration of collaborative elements for students in the form of special webinars to encourage active participation of learners.

Prologue

Program Overview

Subject	PV courses
Study format	Online
Language	English
Type of course	Asynchronous
Duration of study	Different for each course
Homepage	http://pv-iteach.eu/
Fees	Free courses, small fee to issue participation certificate

Courses

The core educational output of PV-iTeach takes the form of a set of online courses related to PV, with each course focusing on a different PV topic. Courses are derived from existing in-person courses at each of the partner universities and enhanced for an online setting. In order to enhance online learning outcomes, a special focus is placed on the integration of collaborative elements for students in the form of special webinars, group projects, etc. to encourage active participation of learners.

Detailed Course Descriptions

The PV-iTeach course catalogue consists of ten PV courses. Detailed descriptions of the respective courses are given below.

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No.	Course Name	Offered by	Lecturer	ECTS
1	Global Energy Needs	Uni Freiburg	Dr. Winfried Hoffmann	5
2	Solar Energy Systems	Uni Freiburg	Prof. Dipl. -Ing. Volker Wachenfeld Dr. Leonhard Probst	6
3	Physics of Solar Cells	Uni Freiburg	Dr. Uli Würfel	6
4	Building Integrated PV Systems	DTU	Dr. Sune Thorsteinsson, Assoc. prof. Sergiu V. Spataru	2.5
5	Applied Photovoltaics	DTU	Assoc. prof. Sergiu V. Spataru, Dr. Sune Thorsteinsson, Markus Babin, Rodrigo Del Prado Santamaria, Dr. Filipe Mesquita Alves Martinho, Daniel Alvarez Mira	5
6	Grid Connected PV Systems	TH Köln	Prof. Dr. Ulf Blieske	5
7	PV Module Technology	TH Köln	Prof. Dr. Ulf Blieske	5
8	Photovoltaic Metrology	FH Münster	Prof. Dr.-Ing. Konrad Mertens	5
9	Solar Radiation and Solar Geometry	DU	Prof. Mats Rönnelid	2.5
10	PV and PV Hybrid System Design	DU	Dr. Frank Fiedler	7.5

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1. Global Energy Needs

ECTS	Lecturer	University
5	Dr. Winfried Hoffmann	Uni Freiburg

Course Content

This course covers the following topics:

0. Introduction
1. Today's energy picture and future energy needs
2. Astonishing predictive power of Price-Experience-Curves
3. Renewable energies – technology, market and economics
4. PV in more detail: physics & technology
5. PV in more detail: market development
6. PV systems, energy storage and integration of renewable technologies
7. Future outlook towards 100% renewables

Learning Objectives

After the course, the students should be able to:

1. Achieve a qualitative and global understanding of today and tomorrow's energy needs.
2. Explain the importance of energy efficiency
3. Construct and use Price Experience Curves to predict the future price trend of mass-produced and globally traded products (like PV modules and batteries).
4. Understand the portfolio of all renewable technologies and their role in power the global needs by 100% renewables.
5. Explain that PV and wind, together with storage, is key to 100% renewable energies.
6. Assess why renewable energy is the best choice to fight climate change.
7. Understand the future renewable energy scenarios published by various organizations (e.g., IEA, BP, and others) and compare these critically with our 100% scenario.

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2. Solar Energy Systems

ECTS	Lecturer	University
6	Prof. Dipl. -Ing. Volker Wachenfeld Dr. Leonhard Probst	Uni Freiburg

Course Content

This course covers the following topics:

1. Off-grid Solar Electricity:
- Energy Poverty and Electricity Access
- Photovoltaic Modules for Off-grid Applications
- Batteries for Off-grid Applications
- Charge Controllers and Maximum Power Point Tracking
- Electrical Loads: Lighting, Water Pumping, Cooling, and Cooking
- System Design with Software Tools
- Mounting / Installation of PV components
- Operation & Maintenance

2. Introduction to Power Grids:
- Concept of AC Power Supply
- Three-phase Electric Circuits
- Mini-grids and Micro-grids
- Structure and Elements of Power Grids
- Grid Operation and Ancillary Services
- Renewable Energy Integration to the Power Grid

Learning Objectives

After the course, the students should be able to:

1. Design and build their solar off-grid system.
2. Program their charge controller and control a solar mini-grid.
3. Understand grid loads of an off-grid system and their effects on the system.
4. Work out an operation and maintenance plan for an off-grid system.
5. Assess the technical and economic aspects of solar off-grid systems.
6. Understand the fundamentals of AC power supply.
7. Distinguish between mini-grid and micro-grid structures.
8. Describe the components and structure of electrical power systems.
9. Explain the principles of frequency control in mini-grid and the utility grid.
10. Formulate the power flow problem for small grid structures.

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11. Understand voltage control for simple examples.
12. Describe the challenges of renewable energy integration for the power grid.

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3. Physics of Solar Cells

ECTS	Lecturer	University
6	Dr. Uli Würfel	Uni Freiburg

Course Content

This course covers the following topics:

- Introduction
- Principle Structure
- Conversion Efficiency and Solar Spectrum
- Limitations of Solar Cell Performance: Spectral and Current Losses
- Limitation of Solar Cell Performance: Voltage Limitation
- Limitation of Solar Cell Performance: Fill Factor Losses

Learning Objectives

After the course, the students should be able to:

1. Understand the fundamental physical processes of photovoltaic energy conversion.
2. Describe the operating principles of photovoltaic devices.
3. Apply the knowledge of photovoltaic energy conversion and operating principles of photovoltaic devices to any kind of solar cell.

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4. Building Integrated PV Systems

ECTS	Lecturer	University
2.5	Dr. Sune Thorsteinsson, Assoc. prof. Sergiu V. Spataru	Denemark Technical University

Course Content

This course covers the following topics:

1. Introduction to building integrated photovoltaics
2. BIPV products
3. BIPV systems
4. Appearance of BIPV systems
5. Course round off

Learning Objectives

After the course, the students should be able to:

1. Explain how BIPV contributes to nearly zero energy buildings and classify BIPV products and applications.
2. Identify how a BIPV project interfaces with the building process.
3. Understand the design process of a BIPV product.
4. Be able to plan a BIPV system.
5. Differentiate between marginal and absolute costs for BIPV.
6. Analyse methods for coloration and improved appearance.
7. Describe glare.

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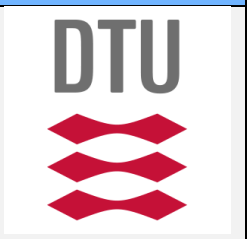
5. Applied Photovoltaics

ECTS	Lecturer	University	
5	Assoc. prof. Sergiu V. Spataru, Dr. Sune Thorsteinsson, Markus Babin, Rodrigo Del Prado Santamaria, Dr. Filipe Mesquita Alves Martinho, Daniel Alvarez Mira	Denemark Technical University	

Course Content

This course covers the following topics:

1. PV module fabrication
2. PV Module Performance Testing
3. Imaging characterization of PV modules
4. Efficiency Characterization of PV Inverters
5. Performance Monitoring of PV Systems
6. Site Shading Analysis

Learning Objectives

After the course, the students should be able to:

1. Understand the components and fabrication process of standard crystalline silicon PV modules
2. Apply and interpret the characterization methods for PV modules
3. Understand and interpret the PV inverter efficiency characterization methods and parameters
4. Understand and apply performance monitoring and parameters of PV systems.
5. Understand and interpret site shading analysis methods.

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6. Grid Connected PV Systems

ECTS	Lecturer	University	
5	Prof. Dr. Ulf Blieske	TH Köln	Technology Arts Sciences TH Köln

Course Content

This course covers the following topics:

- Design of solar cells
- Electrical behavior of solar cells (parameters, main losses)
- Si-Cells & -Modules, Thin-Film-Modules
- PV-System Design
- Properties of PV-Inverters
- Other BOS (cables; mounting; batteries; charge controller)
- Solar radiation (effects of position of the sun, module tilt & azimuth on module performance)
- Grid integration of PV systems
- Safety, ecological and economic evaluation of PV-systems (including feed-in tariff)
- System planning and simulation software

Learning Objectives

After the course, the students should be able to:

1. Plan grid-connected PV-systems with ALL their components
2. Perform analytical calculation and simulation of photovoltaic grid connected systems
3. Analyze the economics and ecology of PV-systems

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7. PV Module Technology

ECTS	Lecturer	University	
5	Prof. Dr. Ulf Blieske	TH Köln	Technology Arts Sciences TH Köln

Course Content

This course covers the following topics:

- C-Si: ALBSF- and PERC technology
- Heterojunction, TOPCON and IBC-technologies
- CIS/CdTe and a-Si
- Concentrator solar cells and modules
- Organic and perovskite solar cells
- Solar glass technology
- Encapsulation materials
- Series connection/junction box/by-pass diode
- Bifacial solar modules
- Solar roof tiles
- Green solar modules: Recycling issues

Learning Objectives

After the course, the students should be able to:

1. Evaluate components (cells, modules, glass, encapsulation…) of PV-systems
2. Analyze future trends in PV module technology (tunnel contacts, tandem cells, organic and perovskite solar cells…)

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8. Photovoltaic Metrology - Sophisticated Methods to Determine the Quality of PV Modules and Plants

ECTS	Lecturer	University	
5	Prof. Dr.-Ing. Konrad Mertens	FH Münster	

Course Content

This course covers the following topics:

1. Why outdoor evaluation? Overview of the course, some PV basics
2. Measurement of global, direct and indirect radiation
3. Measurement of solar module power in the lab
4. Measurement of solar module power at site
5. Thermography (Principle, emission factor, Planck´s law, bright and dark thermography, determination of the state of solar modules…)
6. Indoor Electroluminescence measurements (Principle of measurement, Examples of EL-photos, low-cost-EL, time-efficient setup for low-cost-EL)
7. Outdoor Electroluminescence measurements (Principle of measurement, Examples of EL-photos, low-cost-outdoor-EL, time-efficient setup for lowcost-EL, PID-detection)
8. String-dark-iv-technology (Motivation, measurement method, detection of PID, detection of defect bypass-diodes, detection of defect strings)
9. Dark2Bright-technology (Motivation, principle, advantages and limitations of the method, analytical approach, AI-approach)

Learning Objectives

After the course, the students should be able to:

1. Know, which measuring method is the suitable one to check solar modules and whole plants.
2. Explain, how techniques like thermography and electroluminescence can be used to detect failures in modules and plants.
3. Understand, how even low-cost-outdoor-EL-techniques can be valuable methods to analyse module failures in detail.
4. Describe, how the Dark-IV-Characteristic-Curve-Method accelerates and simplifies the failures examination of PV-strings.
5. Students should have an overview and an insight to PV-quality measurement techniques and are able to choose the appropriate method

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9. Solar Radiation and Solar Geometry

ECTS	Lecturer	University
2.5	Prof. Mats Rönnelid	Dalarna University

Course Content

This course covers the following topics:

1. The sunand extraterrerstrialradiation
2. Sun-earthgeometry
3. Solar angles
4. Visualisation of solar motion – sun path diagram
5. Solar radiation on Earth
6. Measuring solar radiation
7. Calculating angle of incidence
8. Solar radiation data
9. Clearness index
10. Calculation of radiation incident on a surface
11. Anisotropicsky – Hays and Davies model
12. Some rule of thumb

Learning Objectives

After the course, the students should be able to:

1. demonstrate knowledge of the characteristics of solar radiation before and after passage in the atmosphere.
2. control the basic geometry and concepts concerning solar motion and be able to calculate the effect of orientation of a surface on the incident solar energy.
3. review different ways to measure solar radiation and identify the limitations of different measurement methods.
4. understand different kind of solar radiation data and how to use this data for calculations
5. use different models and appropriate approximations for calculating the solar radiation incident on different surfaces

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10. PV and PV Hybrid System Design

ECTS	Lecturer	University	
7.5	Dr. Frank Fiedler	Dalarna University	DALARNA UNIVERSITY

Course Content

This course covers the following topics:

The design of PV off-grid, PV on-grid and PV hybrid systems and in particular:

- the principles of generators for PV systems such as PV modules, small wind turbines and gensets,
- the planning and sizing principles of PV systems,
- PV system applications,
- manual and software based sizing and the optimization of PV systems,
- system architectures and the technical design of PV systems,
- the installation and mounting of PV systems,
- the economic evaluation of PV systems and examples of installed PV systems.

Learning Objectives

After the course, the students should be able to:

1. to describe the main types and concepts of PV and hybrid systems,
2. to understand and apply the principles for planning of PV systems,
3. to independently size different types of PV systems based on basic design procedures and calculations,
4. to have a good command on standard software tools for sizing, modellering and optimization of common PV- and PV hybrid systems,
5. to critically analyse and evaluate the sizing and performance of complete PV systems,
6. to evaluate the economic viability of a PV systems.

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Program Fees and Financing Possibilities

Courses will be open and free to access, while a fee of €80 will be charged for students wishing to receive a certificate to verify their completion of a given course. Students with less financial capacity who will already benefit from the barrier-free, low cost, and accessible education may also apply for a grant which will waive the certificate fee, with a target of 20% of participants being eligible.

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Appendix

About the Project

ERASMUS+ Strategic Partnerships

Call 2020 Round 1 KA2 -Cooperation for innovation and the exchange of good practices

KA226 - Partnerships for Digital Education Readiness

Project title: Photovoltaics Online Teaching (PV-iTeach)

Responsible Persons at the University of Freiburg, M.Sc. Solar Solar Energy Engineering (SEE)

Scientific Director:

Professor Dr. Anke Weidlich

anke.weidlich@inatech.uni-freiburg.de

Chair for Control and Integration of Grids
Solar Info Center,
Emmy-Noether-Straße 2
79110 Freiburg, Germany

Program Coordinators:

Philipp Bucher

bucher@study-solar.uni-freiburg.de

Khadija Khaled Ahmed

khadija.khaled@studysolar.uni-freiburg.de

SEE Program Coordinators
Georges-Koehler-Allee 10
79110 Freiburg, Germany

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Related Departments within the University of Freiburg

Freiburg Academy for University Continuing Education (FRAUW)[1]

FRAUW is a transfer-oriented competence centre for education, training, and continuing education managed as a central operating institution of the university under the responsibility of the Vice-President for Academic Affairs. It consists of three departments: The Department of Academic Continuing Education, which is responsible for the master's program presented here, the Training Department (for the university employees), and the Center for Key Competencies.

FRAUW's task is the professional and interdisciplinary qualification of external persons, employees, and students at the university. Scientific continuing education is seen as a core task of the university. It supports reciprocal transfer with business and society and the numerous positive interactions with undergraduate university teaching, consecutive master's programs, and research. Continuing education and training are part of science communication in the sense of scientific outreach. Impulses from professionals participating in continuing education impact research questions, and the continuing education programs respond to society's needs and perceptions on different levels. ("reciprocal transfer understanding").

The faculties, institutes, and centres are responsible for the content of the academic continuing education programs. FRAUW serves as a central coordination and service platform, bringing support where needed and expanding the University's Lifelong Learning Programs. It also regulates the exchange of services with internal and external continuing education providers based on cooperation agreements. Together with the e-learning department, the University of Freiburg has become a leading university in online master's degree programs addressing professionals worldwide. FRAUW supports its providers in marketing and external representation and is responsible for administrative issues and central networking.

[1] see https://www.wb.uni-freiburg.de/ and https://www.wb.uni-freiburg.de/wb/continuing

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The University of Freiburg's part-time continuing education programs, created in 2007, includes seven online and two face-to-face master's degree programs in medicine, health, technology, law, and taxation. Besides, there are numerous modular study programs and continuing education courses. The continuing education programs are realised in defined quality-assured formats.

The University of Freiburg is the first and, so far only, German university to cooperate with Swissuni, the Swiss Universities Association for Continuing Education. Its quality assurance and formats are based on this model.

E-Learning Department (AEL)[2]

The Department of E-Learning (AEL), located in the University Computer Center, is the central department at the University of Freiburg for digital learning and teaching. It provides a comprehensive IT infrastructure to support innovative teaching scenarios. In cooperation with the Department of University Didactics, the AEL is the central point of contact for all university members concerning consulting, qualification, and support for the use of e-learning and web technologies in teaching. Since 2009, the AEL has provided central support for the university's online continuing education offerings in the following areas:

- Development IT infrastructure for Learning and Teaching
- Didactic-technical consulting and support in the areas of e-learning, media use, and development of online teaching materials
- Qualification and Training

As an interface between technology and its application, the E-Learning Department supports all university members for meaningful integration and the use of digital media and educational technologies in teaching and continuing education programs. Based on service agreements, the e-learning department also provides further support services for continuing education courses, such as content production.

[2] https://www.rz.uni-freiburg.de/go/elearning

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