Module Energy and Resources (ER)

Renewable energy is growing rapidly, with record numbers of new wind and solar installations coming online in Europe over the past few years. Within the next 25 years in Europe, at least 40 percent of our electricity will be produced by renewable energy sources. Therefore, it will be a wise investment to improve the existing electricity system by utilising existing technologies and making smart policy decisions for a clean energy future.

Energy and Resources is an introductory course to energy, reserves and resources which covers the social, economical, environmental and technological background of renewable energy generation. Also, a comprehensive comparison with world oil and gas reserves and a first contact with the PRMS system will take place. Subjects such as: Energy consumption, GHG emission, renewable energy technologies (wind, solar, biomass, bio-fuel, geothermal, hydropower, wave, tidal current, hydrogen fuel cells) will be discussed. The goal of the course is to review the technological potential of renewable energy. At the end of the course the students will learn: How to reduce air pollution, how to decrease the dependence on coal, fossil fuels and nuclear, how to start, design and build a renewable energy system.

Tutors	Prof N. Kokkinos

- **GENERAL**

Title of Module	Energy and Resources (ER)	
Autonomous Teaching Activities	**Total Teaching Hours**	**Credits Units**
Lectures	7	0.4
Language of Tutoring and Examination:	English	

- **EDUCATIONAL OBJECTIVES**

Educational Objectives

The Educational objectives of the thematic unit/course describe the specific knowledge, skills, and abilities of an appropriate level that learners will acquire upon successful completion of the course.

Present and future of RES, measurements of characteristic sizes of different types of PV cells

General Skills

Note the general skills that the trainee acquires. Which of these does the course aim at?
Research, analysis, and synthesis of data and information, using the necessary technologies
Adaptation to new situations
Decision making
Independent work
Teamwork
Working in an international environment
Working in an interdisciplinary environment
Generating new research ideas
Project planning and management
Respect for diversity and multiculturalism
Respect for the natural environment
Demonstrating social, professional, and ethical responsibility and sensitivity to gender issues
Exercise of critical and self-critical thinking
Promotion of free, creative, and inductive thinking

Teamwork, Working in an international environment, Exercise of critical and self-critical thinking, Promotion of free, creative, and inductive thinking, gaining experience from the cooperation of participants of different scientific knowledge and nationalities

- **MODULE CONTENT**

- Energy
- Reserves and resources
- World O&G reserves and resources
- PRMS
- Energy consumption
- GHG emission
- Renewable energy technologies

- **TEACHING and LEARNING METHODS - ASSESSMENT**

Training Method *Physical presence/on-line /blended.*	Physical presence
Use Of Information And Communication Technologies (Ict) *Use of ICT in Teaching, in Laboratory Education, in Communication with Trainees*	All lectures are in Power Point Support of the learning process through an online platform Communication via Email
Evaluation Of Trainees *Description of the evaluation process* *Evaluation Language, Evaluation Methods, Formative or Summative, Multiple Choice Test, Short Answer Questions, Essay Questions, Problem Solving, Written Assignment, Report, Oral Examination, Public Presentation, Laboratory Work, Clinical Patient Examination, Artistic Interpretation, Other* *Explicitly specified evaluation criteria are mentioned and if and where they are accessible to the trainees.*	*Project presentation in Power Point*

- **RECOMMENDED BIBLIOGRAPHY**

1.A.C. Inkpen and M.H. Moffett, The Global Oil & Gas Industry: Management, Strategy & Finance, PennWell Corporation, Tulsa, 2011.
2. U.S. Energy Information Administration, July 2022; http://www.eia.gov.
3. S. Carollo, Understanding Oil Prices: A Guide to What Drives the Price of Oil in Today's Markets, Wiley, Padstow, 2011.
4. D.C. Johnston and D. Johnston, Introduction to Oil Company Financial Analysis, PennWell Corporation, Tulsa, 2006.
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Module Photovoltaic Technologies (PVT)

The direct conversion of sunlight into electricity is a very elegant process to generate environmentally friendly, renewable energy. This branch of science is known as "photovoltaics" or "PV". PV technology is modular, operates silently, is therefore suited to a broad range of applications, and can contribute substantially to our future energy needs. Although the basic principles of PV were discovered in the 19th century, it was not before the 1950s and 1960s that solar cells found practical use as electricity generators, a development that came about through early silicon semiconductor technology for electronic applications. Today, a range of PV technologies is available on the market and under development in laboratories. Complete PV systems consist of two elements: Modules (also referred to as panels), which contain solar cells, and the Balance-of-System (BoS). The BoS mainly comprises electronic components, cabling, support structures and, if applicable, electricity storage or optics & sun trackers. The cost of BoS also includes the labour cost of installation.

In addition, it is worthy of remark to analyse LCC and LCA of various PV technologies. LCC (Life Cycle Cost) of an item consists of the total cost of owning and operating an item over its lifetime. Some costs involved in the owning and operating of an item are incurred at the time of acquisition, and other costs are incurred later. LCA (Life Cycle Assessment) of PV systems is an important tool to quantify the potential environmental advantage of using solar technologies versus more traditional technologies, especially the ones relying on non-renewable fossil fuel sources.

Tutors	Prof N. Kokkinos Georgios Vythoulkas Technical Staff

- **GENERAL**

Title of Module	Photovoltaic Technologies (PVT)	
Autonomous Teaching Activities	**Total Teaching Hours**	**Credits Units**
Lectures	5	1
Language of Tutoring and Examination:	English	

- **EDUCATIONAL OBJECTIVES**

Educational Objectives

The Educational objectives of the thematic unit/course describe the specific knowledge, skills, and abilities of an appropriate level that learners will acquire upon successful completion of the course.

Comparison of 1st, 2nd & 3rd generation PV cell technology.

General Skills

Note the general skills that the trainee acquires. Which of these does the course aim at?

Research, analysis, and synthesis of data and information, using the necessary technologies
Adaptation to new situations
Decision making
Independent work
Teamwork
Working in an international environment
Working in an interdisciplinary environment
Generating new research ideas
Project planning and management
Respect for diversity and multiculturalism
Respect for the natural environment
Demonstrating social, professional, and ethical responsibility and sensitivity to gender issues
Exercise of critical and self-critical thinking

Promotion of free, creative, and inductive thinking
Teamwork, Working in an international environment, Research, analysis, and synthesis of data and information, using the necessary technologies, Exercise of critical and self-critical thinking, Promotion of free, creative, and inductive thinking, gaining experience from the cooperation of participants of different scientific knowledge and nationalities

- **MODULE CONTENT**

Part 1

- PV principles
- Crystalline silicon based technology,
- Types and conversion efficiency of different solar cells architecture

Part 2

- LCC of some PV installations
- Principle of LCC calculation
- Trends and issues: What's Future?

- **TEACHING and LEARNING METHODS - ASSESSMENT**

Training Method *Physical presence/on-line /blended.*	Physical presence
Use Of Information And Communication Technologies (Ict) *Use of ICT in Teaching, in Laboratory Education, in Communication with Trainees*	All lectures are in Power Point Support of the learning process through an online platform Communication via Email
Evaluation Of Trainees *Description of the evaluation process* *Evaluation Language, Evaluation Methods, Formative or Summative, Multiple Choice Test, Short Answer Questions, Essay Questions, Problem Solving, Written Assignment, Report, Oral Examination, Public Presentation, Laboratory Work, Clinical Patient Examination, Artistic Interpretation, Other* *Explicitly specified evaluation criteria are mentioned and if and where they are accessible to the trainees.*	*Project presentation in Power Point*

- **RECOMMENDED BIBLIOGRAPHY**

1. Reliable Performance Comparison of Perovskite Solar Cells Using Optimized Maximum Power Point Tracking, Lucija Rakocevic,* Felix Ernst, Nadine T. Yimga, Saumye ashishtha, Tom Aernouts, Thomas Heumueller, Christoph J. Brabec, Robert Gehlhaar, and Jef Poortmans, 2019 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim
2. Photovoltaic-thermal (PVT) technology: Review and case study C A F Ramos, A N Alcaso and A J M Cardoso Published under licence by IOP Publishing Ltd, DOI 10.1088/1755-1315/354/1/012048
3. Solar Photovoltaics - Fundamentals, Technologies and Applications (English) 3rd Edition 3rd Edition by Chetan Singh Solanki (Author), ISBN-13 978-8120351110, 2015
4. Renewable Energy Engineering and Technology, Taylor & Francis Ltd, 2019, ISBN 9781138866980

http://pv.energytrend.com/
http://pvinsights.com/
http://www.solarbuzz.com/
http://www.iea-pvps.org/

Module Organic & Perovksites Photovoltaics (OPV & PPV)

Organic & Perovksites photovoltaic devices (OPV and PPV respectively) as other organic electronics (OLEDs, sensors, etc.) have the promise to provide lightweight, flexible alternatives to traditional, rigid semiconductor technologies and other inorganic thin film PV technologies. Nowaday, OPV industry is mature for mass production (3 companies in Europe will produce in 2020) and targets new markets like Building Integrated PV (BIPV), Urban Furniture or energy harvesting in the field of the IoT (Internet of Things). At the other hand, PSC technology, based on similar architectures/processes than OPV, reached new power conversion records, up to 23%, and is one on the most discussed topic in the PV world.

First, the principle of Organic and Perovskites technologies will be presented. The course provides an insight into the theory behind these technologies and describes the three main research areas within the field i.e. materials, stability and processing.

Beyond the theoretical aspects, the goal of the course about OPV/PPV is to give a clear pictures of the last industrial developments and market opportunities. The future of these last PV generations will be discussed with students on the basis of the key parameters (technical, cost, market, regulation, politics…) and compared with other PV and renewable technologies.

Tutors	Dr. Stephane Cros, (Senior Scientist, INES)

- **GENERAL**

Title of Module	Organic & Perovksites Photovoltaics (OPV & PPV) Organic materials for photovoltaic applications		
Autonomous Teaching Activities		**Total Teaching Hours**	**Credits Units**
Lectures		14	2
Language of Tutoring and Examination:	English		

- **EDUCATIONAL OBJECTIVES**

Educational Objectives

The Educational objectives of the thematic unit/course describe the specific knowledge, skills, and abilities of an appropriate level that learners will acquire upon successful completion of the course.

Research development of 3rd generation PV cells

General Skills

Note the general skills that the trainee acquires. Which of these does the course aim at?
Research, analysis, and synthesis of data and information, using the necessary technologies
Adaptation to new situations
Decision making
Independent work
Teamwork
Working in an international environment
Working in an interdisciplinary environment
Generating new research ideas
Project planning and management
Respect for diversity and multiculturalism
Respect for the natural environment
Demonstrating social, professional, and ethical responsibility and sensitivity to gender issues
Exercise of critical and self-critical thinking
Promotion of free, creative, and inductive thinking

Teamwork, Working in an international environment, Research, analysis, and synthesis of data and information, using the necessary technologies, Exercise of critical and self-critical thinking, Promotion of free, creative, and inductive thinking, gaining experience from the cooperation of participants of different scientific knowledge and nationalities

- **MODULE CONTENT**

  - 1. Analysis of scientific papers describing specific topics related to OPV or PPV. These “Highlight” papers will selected by groups of students and orally presented.
  - 2. Practical work with OPV devices (measurements in different conditions, realization of systems using OPV energy harvesting).

- **TEACHING and LEARNING METHODS - ASSESSMENT**

Training Method *Physical presence/on-line /blended.*	Physical presence
Use Of Information And Communication Technologies (Ict) *Use of ICT in Teaching, in Laboratory Education, in Communication with Trainees*	All lectures are in Power Point Support of the learning process through an online platform Communication via Email
Evaluation Of Trainees *Description of the evaluation process* *Evaluation Language, Evaluation Methods, Formative or Summative, Multiple Choice Test, Short Answer Questions, Essay Questions, Problem Solving, Written Assignment, Report, Oral Examination, Public Presentation, Laboratory Work, Clinical Patient Examination, Artistic Interpretation, Other* *Explicitly specified evaluation criteria are mentioned and if and where they are accessible to the trainees.*	*Project presentation in Power Point*

- **RECOMMENDED BIBLIOGRAPHY**

1. Organic materials for photovoltaic applications: Review and mechanism, April 014Synthetic Metals 190:20-26, DOI:10.1016/j.synthmet.2014.01.022
2. Advances in Organic and Perovskite Photovoltaics Enabling a Greener Internet of Things, https://doi.org/10.1002/adfm.202200694
3. Improving, characterizing and predicting the lifetime of organic photovoltaics Topical Review Gevorgyan, Suren A.; Heckler, Ilona Maria; Bundgaard, Eva; Corazza, Michael; Hösel, Markus; Søndergaard, Roar R.; Benatto, Gisele Alves dos Reis; Jørgensen, Mikkel; Krebs, Frederik C, DOI: 10.1088/1361-6463/50/10/103001

Module Photovoltaic System Applications (PVS) LCC-LCA of various PV technology

PV systems can be grid connected (work together with the local electrical grid) or work as stand-alone systems (autonomous). Grid-tied systems are the most common type of solar PV system. Grid-tied systems are connected to the electrical grid and allow residents of a building to use solar energy as well as electricity from the grid. Grid-tied systems do not need to produce 100% of the electricity demand for a home or business. When there is no demand for energy, the solar panels send excess electricity back out into the grid for use elsewhere. This course will introduce the design process for several complete self-contained PV systems and grid-tied systems.

Tutors	Prof D. Abbes, (HEI)

- **GENERAL**

Title of Module	Photovoltaic System Applications (PVS) LCC-LCA of various PV technology		
Autonomous Teaching Activities		**Total Teaching Hours**	**Credits Units**
Lectures		12	1.2
Language of Tutoring and Examination:	English		

- **EDUCATIONAL OBJECTIVES**

Educational Objectives

The Educational objectives of the thematic unit/course describe the specific knowledge, skills, and abilities of an appropriate level that learners will acquire upon successful completion of the course.

Introduction on the design process for several complete self-contained PV systems and grid-tied systems

General Skills

Note the general skills that the trainee acquires. Which of these does the course aim at?
Research, analysis, and synthesis of data and information, using the necessary technologies
Adaptation to new situations
Decision making
Independent work
Teamwork
Working in an international environment
Working in an interdisciplinary environment
Generating new research ideas
Project planning and management
Respect for diversity and multiculturalism
Respect for the natural environment
Demonstrating social, professional, and ethical responsibility and sensitivity to gender issues
Exercise of critical and self-critical thinking
Promotion of free, creative, and inductive thinking

Teamwork, Working in an international environment, Research, analysis, and synthesis of data and information, using the necessary technologies, Exercise of critical and self-critical thinking, Promotion of free, creative, and inductive thinking, gaining experience from the cooperation of participants of different scientific knowledge and nationalities

- **MODULE CONTENT**

Part 1: PV systems applications

- An overview of applications
- Stand-alone systems:
  - Components and conversion chain
  - MPPT
  - System design

- Grid-tied systems:
    - Integration of PV generators to the grid
    - Conversion chain
    - Power converters associated to grid-tied PV systems
    - Regulations and policies
    - Grid services
    - Hybridization of electrical energy storage for intelligent integration of PV in electric networks

Part 2: Simulation of a case study

- **TEACHING and LEARNING METHODS - ASSESSMENT**

Training Method *Physical presence/on-line /blended.*	Physical presence
Use Of Information And Communication Technologies (Ict) *Use of ICT in Teaching, in Laboratory Education, in Communication with Trainees*	All lectures are in Power Point Support of the learning process through an online platform Communication via Email
Evaluation Of Trainees *Description of the evaluation process* *Evaluation Language, Evaluation Methods, Formative or Summative, Multiple Choice Test, Short Answer Questions, Essay Questions, Problem Solving, Written Assignment, Report, Oral Examination, Public Presentation, Laboratory Work, Clinical Patient Examination, Artistic Interpretation, Other* *Explicitly specified evaluation criteria are mentioned and if and where they are accessible to the trainees.*	*Project presentation in Power Point*

- **RECOMMENDED BIBLIOGRAPHY**

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Working Paper : RENEWABLE ENERGY TECHNOLOGIES: COST ANALYSIS SERIES , Solar Photovoltaics , Volume 1 ,Issue 4/5, June 2012.
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Kersten , F. et al. (2011), PV Learning Curves: Past and Future Drivers of Cost Reduction, Proceedings of the 26th European Photovoltaic Solar Energy Conference , 5 9 September, Hamburg
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Solarbuzz (2011), Annual World PV Market Review, Solarbuzz , 12 April 2011, Port Washington, NY

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Goodrich, A.; T. James and M. Woodhouse (2012), Residential, Commercial, and Utility Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost Reduction Opportunities NREL, Golden, CO

[10]

EPIA and A.T. Kearney (2011), Solar Photovoltaics: Competing in the Energy Sector , EPIA,

Module Modeling and Simulation in Energy Engineering (MSEE)

Modelling and simulation is a powerful tool for the conceptual design, operational analysis and optimization of energy engineering components, systems and processes. Modelling and simulation activities can reduce product design time and time to market and improve product performance, efficiency, and quality. The aim of this course is to introduce students to the methodologies and tools involved in the modelling and simulation of advanced energy systems in general and PV systems in particular. The students should be able to (1) formulate, mathematically describe, numerically solve and analyse energy conversion processes, using advanced numerical tools and (2) perform techno-economic analyses for the integration of PV units in energy systems.

Tutors	Dr. Moez Belhaouane, (HEI)

- **GENERAL**

Title of Module	Modeling and Simulation in Energy Engineering (MSEE)		
Autonomous Teaching Activities		**Total Teaching Hours**	**Credits Units**
Lectures		12	1
Language of Tutoring and Examination:	English		

- **EDUCATIONAL OBJECTIVES**

Educational Objectives

The Educational objectives of the thematic unit/course describe the specific knowledge, skills, and abilities of an appropriate level that learners will acquire upon successful completion of the course.

On successful completion of the course, students will be able to:

- Comprehend the basic principles of modelling and simulation of energy systems.
- Demonstrate the ability to formulate, mathematically describe, numerically solve and analyse solar energy conversion processes, using advanced numerical tools such as CFD.
- Demonstrate the ability to assess the technical and economic performance of PV units and their integration into the energy system

General Skills

Note the general skills that the trainee acquires. Which of these does the course aim at?
Research, analysis, and synthesis of data and information, using the necessary technologies
Adaptation to new situations
Decision making
Independent work
Teamwork
Working in an international environment
Working in an interdisciplinary environment
Generating new research ideas
Project planning and management
Respect for diversity and multiculturalism
Respect for the natural environment
Demonstrating social, professional, and ethical responsibility and sensitivity to gender issues
Exercise of critical and self-critical thinking
Promotion of free, creative, and inductive thinking

Teamwork, Working in an international environment, Research, analysis, and synthesis of

data and information, using the necessary technologies, Exercise of critical and self-critical thinking, Promotion of free, creative, and inductive thinking, gaining experience from the cooperation of participants of different scientific knowledge and nationalities

- **MODULE CONTENT**

- Fundamentals of Energy Systems Design (Mass and energy balances, Energy efficiency, Environmental assessment).
- Introduction to Modelling and Simulation (Multiscale physics-based models, Performance-based models, System integration).
- Energy Performance and Financial Feasibility of PV Systems (Energy model, Cost analysis, GHG analysis, Financial analysis)
- Thermal Performance of PV Panels (Problem formulation, Geometry modelling, Meshing, Boundary and initial conditions, Physical models and input parameters, Run simulation, Post-process results)
- Hands-on computations using the ANSYS Student and RETScreen software platforms.

- **TEACHING and LEARNING METHODS - ASSESSMENT**

Training Method *Physical presence/on-line /blended.*	Physical presence
Use Of Information And Communication Technologies (Ict) *Use of ICT in Teaching, in Laboratory Education, in Communication with Trainees*	All lectures are in Power Point Support of the learning process through an online platform Communication via Email
Evaluation Of Trainees *Description of the evaluation process* *Evaluation Language, Evaluation Methods, Formative or Summative, Multiple Choice Test, Short Answer Questions, Essay Questions, Problem Solving, Written Assignment, Report, Oral Examination, Public Presentation, Laboratory Work, Clinical Patient Examination, Artistic Interpretation, Other* *Explicitly specified evaluation criteria are mentioned and if and where they are accessible to the trainees.*	*Project presentation in Power Point*

- **RECOMMENDED BIBLIOGRAPHY**

1. Modeling and Simulation of Energy Systems, ISBN978-3-03921-519-5 (PDF), 2019
2. Simulation modeling for energy systems analysis: a critical review, DOI: https://doi.org/10.1186/s42162-024-00374-8. 2024

Module Photovoltaic Systems: Performance, Reliability and Emerging Challenges in O&M

The content of this course provides a comprehensive overview of the theoretical elements, key concepts, best practices and technical challenges related to the performance, reliability and O&M of PV systems. In Part 1, a particular focus is given on the better understanding and insights into: i) PV performance indicators, monitoring and forecasting methods and safety on the operational side and ii) PV reliability and underperformance issues in the field, diagnostics/inspections and preventive/corrective actions on the maintenance side. Part 1 closes with a presentation and discussion on recent technological advances and opportunities of the PV research community and industry in (and towards) the Industry 4.0 and Circular Economy eras. The part 2 of this course comprises of a practical example/case study, focusing on hands-on understanding of actual performance and reliability aspects in real-life operating PV plants. In this case, the return of experience from PV systems inspections will be presented, in an interactive way with (open questions from/to) the attendees of this course.

The content of this course is addressed to a multidisciplinary audience: undergraduate and postgraduate students, young researchers, as well as professionals (engineers, technicians) relevant to and interested in renewable energy systems and particularly solar PV technology, systems and applications.

Tutors	Dr. Ioannis Tsanakas, (Scientist, INES)

- **GENERAL**

Title of Module	Photovoltaic Systems: Performance, Reliability and Emerging Challenges in O&M		
Autonomous Teaching Activities		**Total Teaching Hours**	**Credits Units**
Lectures		12	1.2
Language of Tutoring and Examination:	English		

- **EDUCATIONAL OBJECTIVES**

Educational Objectives

The Educational objectives of the thematic unit/course describe the specific knowledge, skills, and abilities of an appropriate level that learners will acquire upon successful completion of the course.

The technical and economic importance of PV systems' performance, reliability and O&M.

Development and innovation (RDI), both at Industrial and at Research/Academic level. In parallel, new RDI challenges (and, thus, opportunities) emerge the last few years, with the increasing importance of two overarching topics in PV industry and O&M agenda: the circular economy (sustainability, in overall) and the digitalization

General Skills

Note the general skills that the trainee acquires. Which of these does the course aim at?

Research, analysis, and synthesis of data and information, using the necessary technologies
Adaptation to new situations
Decision making
Independent work
Teamwork
Working in an international environment
Working in an interdisciplinary environment
Generating new research ideas
Project planning and management

Respect for diversity and multiculturalism *Respect for the natural environment* *Demonstrating social, professional, and ethical responsibility and sensitivity to gender issues* *Exercise of critical and self-critical thinking* *Promotion of free, creative, and inductive thinking*
Teamwork, Working in an international environment, Research, analysis, and synthesis of data and information, using the necessary technologies, Exercise of critical and self-critical thinking, Promotion of free, creative, and inductive thinking, gaining experience from the cooperation of participants of different scientific knowledge and nationalities

- **MODULE CONTENT**

Part 1

- Introduction – Basic elements
- O&M and Performance of PV systems
  - Performance indicators
  - Monitoring and Forecasting
  - Safety considerations
- O&M and Reliability of PV systems
  - Losses and Failure Mechanisms
  - Maintenance actions and strategies
  - Characterization, diagnostic and inspection methods
- Emerging Challenges
  - Towards sustainability: PV in the Circular Economy era
  - Towards digitalization: PV in the Industry 4.0 era

Part 2: Return of experience from real PV system inspections (Case Study)

- **TEACHING and LEARNING METHODS - ASSESSMENT**

Training Method *Physical presence/on-line /blended.*	Physical presence
Use Of Information And Communication Technologies (Ict) *Use of ICT in Teaching, in Laboratory Education, in Communication with Trainees*	All lectures are in Power Point Support of the learning process through an online platform Communication via Email
Evaluation Of Trainees *Description of the evaluation process* *Evaluation Language, Evaluation Methods, Formative or Summative, Multiple Choice Test, Short Answer Questions, Essay Questions, Problem Solving, Written Assignment, Report, Oral Examination, Public Presentation, Laboratory Work, Clinical Patient Examination, Artistic Interpretation, Other* *Explicitly specified evaluation criteria are mentioned and if and where they are accessible to the trainees.*	*Project presentation in Power Point*

- **RECOMMENDED BIBLIOGRAPHY**

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Renewable and Sustainable Energy Reviews, A. Foley, Queen's University Belfast, Belfast, Northern Ireland, UK, https://doi.org/10.1016/S1364-0321(24)00079-0
Review of Photovoltaic System Reliability Challenges and Opportunities, EPRI, Palo Alto, CA: 2012. 1024002.