**Modernising Undergraduate Renewable Energy Education: EU Experience for Jordan**

**TEMPUS Project Number 530332**

**Princess Sumaya University for Technology**

**Report on DEV2.2**

“Selection of Pilot Courses and Labs”

**Introduction**

According to DEV2.2 of MUREE project which foresees the updating and improving of contents for 4 state-of-the-art courses and then the delivering, accrediting and adapting to add value to the existing programme at PSUT and all Jordanian universities, partners of MUREE, the following report has been prepared. As indicated in the proposal, among 4 courses, 1 course will be taught in other beneficiary universities at university requirements and 1 at faculty level. Sapienza, as leader of WP 2, coordinates all activities for the elaboration of syllabus and courses’ contents. DEV2.2 foresees the identifying of 4 pilot courses, the e-learning course and the labs, in traditional and remote way.

**Pilot Courses**

During the last meeting in Graz, 10-11th of April 2013, MUREE partners have approached the topic of “Selection of Pilot Courses and Labs, starting from the Report on Labour Market needs, elaborated by JUST. The following pilot courses have been chosen, 4 for in presence learning and 2 for distance learning:

1. Energy Conversion (in presence)
2. Renewable Energy Systems (in presence and in distance learning)
3. Photovoltaic (in presence and in distance learning)
4. Solar Thermal Energy (in presence)
5. Wind Energy (in presence)
6. Electric machines and drive (in presence)

Some Jordanian Partners have declared to have part of listed courses in the university curricula and internal expertise for didactic. The experience of these partners is the starting point for the development of the new and updated programmes and materials. In according with what decided during the meeting, the development of each course is carried on by one Jordanian partner, as leader, and Jordanian and European partners as collaborators. The following table shows Jordanian partners which have in the university curricula the chosen courses, European partner involved in the development of updated version, Jordanian leader and other partners which support the elaboration of didactic materials and syllabus.

<table>
<thead>
<tr>
<th>Course name</th>
<th>PSU T</th>
<th>UJ</th>
<th>MUTAH</th>
<th>HU</th>
<th>JUST</th>
<th>EU</th>
<th>Leaders from Jordan</th>
<th>Partners</th>
<th>Persons involved</th>
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<tbody>
<tr>
<td>Energy conversion</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Sapienza</td>
<td>PSUT, MUTAH</td>
<td>Katiuscia, Ahmad + Odah</td>
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<tr>
<td>RE systems</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Sapienza</td>
<td>PSUT, UJ, MUTAH</td>
<td>Katiuscia, Bashan + Ahmad + Handri + Khasw</td>
</tr>
<tr>
<td>PV</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>UCY</td>
<td></td>
<td></td>
<td>Maria, Issa, Mohamet + Monsoon</td>
</tr>
<tr>
<td>Solar Energy (thermal)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>TU Berlin</td>
<td>MUTAH</td>
<td>Jens, Ayman M + Klaus</td>
</tr>
<tr>
<td>Wind energy</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>TU Berlin</td>
<td>JUST</td>
<td>Jens, Suhil, Maiteh</td>
</tr>
<tr>
<td>Electric machines</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>RE in</td>
<td>TU Graz</td>
<td>PSUT</td>
<td>Annette, Ayman F, Klaus</td>
</tr>
</tbody>
</table>
Leader’s DEVs:
- Driving the elaboration of course for which is leader,
- Provide European partner(s) information for the development of the definitive contents in according to the National and University needs.

Main activities for DEV2.2:
1. Jordanian and European partners work together in the elaboration of courses’ syllabus;
2. Jordanian partners verify the syllabus and send to European partners the definitive version;
3. Jordanian partners elaborate a course description and all the information for the request of accreditation;
4. European partners send a general curriculum content and expect feedback from Jordanians on making the course customized to their needs, and send more help back;
5. Jordanian partners request the development of detailed course material, and ask each EU partner to send what they have;
6. EU universities request Jordanians to send them the program of their courses they given.
All the activities are managed by Sapienza and TUG in collaboration with all Jordanian partner universities. HU will include in the report the technical specifications for the e-learning courses.

Laboratories
In addition to the 6 updated courses, 2 labs, and 4 remote labs and an educational solar/wind station have to be established. Following the indication of DEV2.3:
- TUB and UCY are responsible for the design of traditional labs;
- UNED and HU are responsible for the design of e-learning courses and remote labs;
- UCY and PSUT are responsible for the design of the station.

Traditional Laboratory
PSUT Power and Energy traditional labs intend to demonstrate explain and relate the link between the renewable energy and the actual electric power systems and machines. Being able to demonstrate the fundamental characteristics and capabilities of the power electronics devices, allows the student to understand the operation of the converters used to integrate between the renewable energy sources and the power systems, contributing into a better understanding of what so called the ‘Smart Grid’, as well the use of these converter devices for efficient driving and controlling of the electric motors and generators. The equipment to be purchased and topics to be covered for the electric machines and power electronics lab space, in order to achieve the desired objectives above:
- Performance Characteristics of motors
  - Single phase induction motor
  - Three-Phase induction motor
  - Reluctance motor
- Power Electronics Converters :
  - DC Choppers.
  - AC inverters.
  - Frequency Converters
  - Servo-Drives
The labs will offer students the chance to investigating the characteristics, and operational states of power systems that integrate renewable energy with conventional generation methods and its transmission and distribution as well. Furthermore, determination of the different power systems parameters of transmission lines and substations of the grid associated with the power quality metering standards. The labs will explain and demonstrate some modern energy management systems making use of SCADA systems and smart energy metering devices. Also, it will introduce students to the coordination and communication between the protective equipment installed over the ‘Smart Grid’, as well as the fundamental characteristics of this protection equipment.
The equipment to be purchased and topics to be covered for the electric machines and power electronics lab space, in order to achieve the desired objectives above:

- Power systems & Protection:
- Double bus bar systems characteristics.
- Transmission lines parameters.
- Smart Grid Software.
- SCADA.
- Power Protection Relays. (Differential & Overcurrent)

The power systems laboratory will include transmission lines, substations models; able to demonstrate a model of a smart grid, as well with the protection devices of that system. UNED and HU to include in the report all information on remote labs they have at the moment. UCY and PSUT to include in the report all information on the station they have at the moment.

Remote labs
Equipment for remote labs established will be installed in HU, PUST, JUST, MUTAH:
(i) Wind and solar power trainer setup: teach students characteristics of solar panels and wind power generators,
(ii) Alternative energy trainer: theory of generating power from solar, wind, fuel cells,
(iii) Power quality trainer: analysis tools,
(iv) Solar tracking control trainer.

Action Plan
The following action plan is based on the deadline of MUREE project and intends to support the achievement of the deliverables:

<table>
<thead>
<tr>
<th>Deliverables</th>
<th>Partners involved</th>
<th>Deadline [dd/mm/yyyy]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dev 2.3 - Detailed Design of Pilot Courses</td>
<td>All partners</td>
<td>15/08/2013</td>
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<tr>
<td>– Comments and suggestions concerning the courses</td>
<td>All partners</td>
<td>30/08/2013</td>
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<tr>
<td>– Final Version of the report and syllabus</td>
<td>Sapienza/TUG</td>
<td>03/09/2013</td>
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<tr>
<td>– List of topics for which didactic materials are missed</td>
<td>Jordanian Partners</td>
<td>06/09/2013</td>
</tr>
<tr>
<td>– Elaboration of missed Didactic materials</td>
<td>All partners</td>
<td>27/9/2013</td>
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<tr>
<td>Dev 2.4 – Accreditation of New Curricula</td>
<td>Jordanian Partners</td>
<td>15/04/2014</td>
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<td>Dev 2.5 – New Curricula for RE Courses</td>
<td>All partners</td>
<td>15/10/2014</td>
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<tr>
<td>Dev 2.6 – Labs and Educational Station on RE</td>
<td>All partners</td>
<td>15/10/2014</td>
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<tr>
<td>Dev 2.7 – Monitoring and Feedback Methodology and Reports</td>
<td>Sapienza</td>
<td>15/12/2014</td>
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</table>
Annex I
Title of pilot course: Energy Conversion
Credits: Three-credit hour course
Pre-requisites: …
Level: Junior-senior level

Contents:
[UnJ Proposal]
1. Energy classification, resources and utilization.
2. Principal fuels for energy conversion.
3. Production of thermal energy.
4. Fossil fuel systems.
5. Environmental impact of power plant operation.
6. Production of electrical energy (by direct energy conversion).
7. Wind energy.
8. Solar energy.

Detailed contents:
[Sapienza’s Proposal]
1. Introduction to the energy problem (X hours)
   Energy cycle, energy classification, energy sources
   Difference between conventional and renewable sources
   Classification of primary and secondary sources
   Energy balance of the Heart

2. Conventional Systems (X hours)
   Principal fuels for energy conversion
   Classification of fluid machines
   Classification of the energy conversion plants
   Main thermodynamic cycles
   Steam Power
   Gas turbine
   Nuclear fission and fusion
   Vapour compressor
   Absorption refrigeration

3. Direct Conversion (X hours)
   Thermionic power conversion
   Thermoelectric effect (Seebeck effect, Peltier effect, Thomson effect)
   MHD – Magnetohydrodynamic

4. Renewable Energy Systems (X hours)
   Wind energy
   Photovoltaic cells
   Solar concentration
   Solar thermal technology (Low, medium and High temperature)
   Geothermal energy
   Hydrogen and fuel cells
   Biomass and Biofuel

Note:
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Text Book:
...

Additional references:
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Practical:
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...
Title for pilot course: **Renewable Energy Systems**
Three-credit hour course
Pre-requisites: ….
Level: Junior-senior level

**Contents:**
1. Introduction
2. Photovoltaic
3. Solar Thermal
4. Wind
5. Biomass/fuel
6. Hydropower
7. Geothermal

**Detailed contents:**
1. **Introduction (3 hours)**
   Energy situation in Jordan
   Energy situation in the world
   Renewable energy sources

2. **Photovoltaic (11 hours)**
   Introduction
   Fundamentals of solar radiation
   Solar radiation measurements and availability
   Sun path description and calculations
   Silicon
   Solar cells
   Components
   Panels
   Inverters
   Solar charge controller
   Solar batteries
   Loads
   Theory
   Photovoltaic systems
   On- and Off-grid
   Trackers and non-trackers
   Modules and arrays
   Efficiency and MPP
   I-V curves under standard test conditions
   Temperature, insolation, and shading impacts
   Smart grid
   Design
   Economics
   Software

3. **Solar Thermal (13 hours)**
   Introduction
   Structure
   Operation
   Components and Theory
   Flat-plate collectors
   Air-based collectors
   Vacuum-tube collectors
Parabolic troughs
Heliostats
Thermal systems (free and forced circulations)
Solar cooling
Solar power plants
Thermal performance
Design
Economics
Software

4. Wind (10 Hours)
Introduction
Wind energy sources
Wind turbine types
Wind turbine operation
Wind farms
Power coefficient
Components
Rotors
Blades
Gearboxes
Wind Turbine generators
Measurements and controllers
Charges
Theory
Impart of tower height
Rotor efficiency
Speed control
Grid-connected wind turbine
Performance calculations
Design
Economics
Software

5. Biomass/fuel (8 hours)
Origin
Fundamentals
Availability
Characteristics
Biofuels
Products

6. Hydropower (4 hours)
Introduction
Turbines
Plants
Theory
Hydraulic analysis
Turbine speeds
Energy transfer in turbines

7. Geothermal (4 hours)
Introduction
Theory
Resources
Geothermal energy systems
Geothermal heat pumps

Note:
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Text Book:
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Additional references:
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Practical:
...
Title for pilot course: **Photovoltaic Systems**
Three-credit hour course  
Pre-requisites: Electronics I (semiconductor materials, diodes, transistors, feedback circuits)  
Level: Junior-senior level

**Contents:**

1. Introductory overview  
2. The solar resource  
3. Semiconductor physics  
4. Solar cells  
5. PV array and modules  
6. PV systems  
7. Distributed versus centralized solar PV generation, BOS design, Intro to smart-grid for PV systems  
8. Recent advances and challenges in PV systems: Addressing continued challenges: concerns with high penetration, grid stability, cost, dust, high temperature, reliability, intermittency, and dynamically instable energy.  
Introduction to BIPV, energy management and energy policy and regulations  
9. Practical challenges that need to be addressed ... PV installations

**Detailed contents**  
1. **Introduction overview (3 hours)**  
   Overview of Energy  
   Environmental and Social threats  
   Energy Crisis  
   Solar Potential  
   Photovoltaic applications and market potentials  
   Photovoltaic energy in Jordan  

2. **The solar resource (6 hours)**  
   The solar spectrum  
   The earth’s orbit  
   Altitude angle of the sun at Solar Noon  
   Solar position at any time of day  
   Sun path diagrams for shading analysis  
   Clear sky direct-beam radiation  
   Total clear sky insolation on a collecting surface

3. **Semiconductor physics (6 hours)**  
   Intro  
   Basic semiconductor physics  
   A generic PV cell  
   From cells to modules to arrays  
   The PV I-V curve under STC  
   Impacts of temperature and insolation on I-V curves  
   Shading impacts on I-V curves

4. **Solar cells (8 hours)**  
   Solar cell structure  
   Collection probability  
   Spectral response  
   Photovoltaic Effect  
   Operation parameters  
   Effect of Parasitic resistance  
   Effect of temperature
Effect of Irradiance
Solar Cell - Manufacturing
Introduction to major PV technologies
Introduction to manufacturing of solar cells
I-V curves for loads
Stand alone and Grid-connected systems and economics

5. PV modules and array (5 hours)
PV system analysis
Module performance
PV interconnection effects
Reasons for underperformance

6. PV systems (10 hours)
PV markets and driving forces
PV systems
PV system performance
PV system design and sizing ... components
PV tracking systems
PV performance
Energy prediction
PV Business – Manufacturing Costs

7. Distributed solar PV generation (6 hours)
Distributed (DG) versus centralized solar PV generation
BOS design
Intro to smart grids: advanced metering infrastructure AMI
Micro-grids

8. Recent advances and challenges in PV systems (4 hours)
Challenges of high penetration, dynamic pricing – cost issues,
Introduction to BIPV,
Energy management
Policy

9. Practical challenges that need to be addressed ... PV installations (3 hours)

Note:
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Text Book:

Additional references:

Practical:
PV cell characterization
Title for pilot course: Wind Energy
Three-credit hour course
Pre-requisites: Fluid Mechanics, Electric machine, Energy Conversion
Level: Junior-senior level

Contents:
1. Introductory overview
2. Wind Characteristics and Resources
3. Aerodynamics of Wind Turbines
4. Wind energy conversion systems
5. Performance of wind energy conversion systems
6. Electrical Aspects of Wind Turbines
7. Wind Turbine Control
8. Economics of wind energy

Detailed contents:
1. Introduction overview (X hours)
   Modern Wind Energy Convertors
2. Wind Characteristics and Resources (X hours)
   General Characteristics of the Wind Resource
   Characteristics of the Atmospheric Boundary Layer
   Wind Data Analysis and Resource Estimation
   Wind Turbine Energy Production Estimates Using Statistical Techniques
   Wind Measurements and Instrumentation
   Overview of Available Resource Assessment Data

3. Aerodynamics of Wind Turbines (X hours)
   One-Dimensional Momentum Theory and the Betz Limit
   Ideal Horizontal Axis Wind Turbine with Wale Rotation
   Airfoils and General Concepts of Aerodynamics
   Momentum Theory and Blade Element Theory
   Blade Shape for Ideal Rotor without Wake Rotation
   General Rotor Blade Shape Performance Prediction
   Blade Shape for Optimum Rotor with Wake Rotation
   Generalized Rotor Design Procedure
   Simplified HAWT Rotor Performance Calculation Procedure
   Effect of Drag and Blade Number on Optimum Performance
   Advanced Aerodynamic Topics

4. Wind energy conversion systems (X hours)
   Wind electric generators: Tower, Rotor, Gear box, Power regulation, Safety brakes, Generator
   Wind farms

5. Performance of wind energy conversion systems (X hours)
   Power curve of the wind turbine
   Energy generated by the wind turbine; Weibull based approach and Rayleigh based approach
   Capacity factor
   Matching the turbine with wind regime
   Performance of wind powered pumping systems
   Wind driven piston pumps
   Wind driven roto-dynamic pumps
   Wind electric pumping systems

6. Electrical Aspects of Wind Turbines (X hours)
Overview
Basic Concepts of Electric Power
Power Transformers
Electrical Machines
Power Converters

7. Wind Turbine Control (X hours)
Overview of Wind Turbine Control Systems
Typical Grid-connected Turbine Operation
Supervisory Control Overview and Implementation
Dynamic Control Theory and Implementation

8. Economics of wind energy (X hours)
Factors influencing the wind energy economics
Site specific factors
Machine parameters
Energy market
Incentives and exemptions
The ‘present worth’ approach
Cost of wind energy
Initial investment
Operation and maintenance costs
Present value of annual costs
Benefits of wind energy
Net present value
Benefit cost ratio
Pay-back period

Note:
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Text Book:
...

Additional references:
....

Practical:
...
Title of pilot course: Introduction to Electric Machines and Drives
Credits: Three-credit hour course
Pre-requisites: …
Level: Junior-senior level

Contents:
1. Motivation
2. Review: Electromagnetics and Energy Conversion
3. Review: AC Systems and Three-Phase Circuits
4. Basics of AC Machines
5. Synchronous Machines: Steady State
6. Induction Motors: Steady State
7. Converter Power Electronics: Basic Theory, Devices
8. AC Inverter Basics: VSI, Modulation
9. Adjustable Speed Drives: Basics
10. Field oriented control (Special case: Field Oriented Control of Induction Motors)
11. Adjustable Speed Drives: Volts/Hz Control
12. Adjustable Torque Drives: Basics
13. Synchronous machine control

Detailed contents:
1. Motivation (1 hr)
   Load types and characteristics
   Practical issues of machine and drive selection

2. Review: Electromagnetics and Energy Conversion (2 hrs)
   Ampere’s law
   Faraday’s law
   Gauss’s magnet law
   Magnetic circuits: electrical-magnetic analogy
   Magnetic flux
   Soft magnetic materials
   Inductors and transformers
   Forces: Lorentz and Reluctance
   DC machine

3. Review: AC Systems and Three-Phase Circuits (2 hrs)
   AC voltages and currents
   Complex numbers and phasor concepts
   Why three-phase?
   Harmonics
   Per-unit system

4. Basics of AC Machines (4 hrs) (Spend more time on fundamentals)
   Elementary AC machines- air-gap MMF- flux- voltage waveforms
   Distributed stator windings
   Elementary rotor-stator coupling
   Three-phase operation

5. Synchronous Machines: Steady State (1 hr+2hrs as time permits)
   Synchronous machine types- smooth rotor- salient pole- permanent magnet
   Circuit models and vector diagrams
   Capability curves

6. Induction Motors: Steady State (1hr+2hrs as time permits)
   Induction machine types- wound rotor- “squirrel cage” rotor
Circuit models
Definition of slip
Torque-speed curves

7. Converter Power Electronics: Basic Theory, Devices (3 hrs)
Review of circuit fundamentals
Basic converters: AC-DC, DC-DC, DC-AC, AC-AC
Higher focus on DC-DC, and DC-AC. Mention buck and boost converters
Device characteristics and capabilities

8. AC Inverter Basics: VSI, Modulation (3 hrs)
Basic inverter system
Voltage source inverter (VSI)
Modulation techniques
Pulse width modulation (PWM)
Practical considerations

9. Adjustable Speed Drives: Basics (3 hrs)
Basic adjustable speed drive systems
Review: DC machine:
9. Speed control
10. Torque control
11. Cascaded control
12. Field weakening
Varying voltage
Motor and drive selection

10. Field oriented control (Special case: Field Oriented Control of Induction Motors) (4 hrs)
Revisit IM model
Physical representation of induction machine fields
Basic IM vector drive
Rotor flux orientation
Field weakening
Induction machine torque-slip control

11. Adjustable Speed Drives: Volts/Hz Control (1 hr)
Concepts of constant flux and torque
Operation at constant torque or power
Low speed operation
Basic Volts-per-Hertz system
Drive limitations

12. Adjustable Torque Drives: Basics (1 hr)
Ideal adjustable torque systems

13. Synchronous machine control (2 hrs)
Synchronous machine control (notably PM machines)

14. Application-Specific Selection of Machine-and-Drive Systems (1 hr)
Specific drives to suit application
Case study

Note:
If time permits, go back and talk more about steady state synchronous machines and induction machines (up to 4 hrs)

Text Book:
Introduction to Electric Machines and Drives; T. M. Jahns, T. A. Lipo, and D. W. Novotny.

Additional references:
“Electric Drives” and “Advanced Electric Drives” by Ned Mohan

Practical:
Experiments on speed control of synchronous Machines, Induction Machines, and Reluctance Machines
Title for pilot course: **Solar Thermal Systems**
Three-credit hour course
Pre-requisites: thermodynamics
Level: Junior-senior level

**Contents:**
1. Fundamentals
2. Design and installation
3. Fields of application
4. Concentrating solar power

**Detailed contents:**

**1. Fundamentals**

**Physics:**
Basics in thermodynamics
Heat transfer (conduction, convection, radiation)
Basics in fluid mechanics

**Components:**
Solar Collectors
- DEV, function and characteristic values
- Collector types
Flow type and hydraulic characteristics
Solar Storage Unit
- Function and Requirements
- Types of construction and advanced storage technologies
Heat Exchangers
- Function and requirements
- Construction types
Collector Loop:
- Types of systems
- Heat transfer fluids and characteristics
Pumps and accessories

**2. Design and Installation**

System design and configuration
- Design of households’ size water and space heating systems
- Feasibility assessment, site survey
- Energy consumption assessment
- Collector array angles and orientation
- Combination with other fossil and renewable energy sources
- Calculating output
Economics
- Loads and applicable building regulation (wind speeds, snow etc.)
- Dimensioning of collectors, storage units and collector loop
Pipe dimensioning, hydraulic configuration and pressure losses

System Installation
- Selection of components and assembling
- Collector Mounting
- Assembly on a sloped roof
- Rigging on a flat roof
- Building integration
- Inspection and testing of the system
- Operation and Maintenance
- Monitoring system performance
- Possible malfunctions and trouble shooting
3. Fields of Application for Solar Thermal Systems
Basics of Solar Thermal technologies:
  - Functionality
  - Required conditions
  - Efficiencies
  - Characterization
Motivation, potential und market development for Solar Thermal Systems
Kinds of solar thermal collectors
  - Temperature ranges
  - Basics radiation
  - Physics for collectors
  - Basics of power generation
Applications in the residential sector
  - Space/water heating and cooling
  - Cooking
  - Drying
Industrial applications:
  - Process Heat
  - Desalination
  - Drying
  - Preheating
Solar assisted heat networks: Local and district heating.
Energy storing possibilities

4. Concentrating Solar Power
Conventional Steam Power Plant technology
  - Fundamentals in thermodynamics of steam power plants
  - Conventional steam power plants
CSP
  - Overview on different CSP technologies, system types, solar and hybrid systems, pros and cons of
  - Different technologies, market overview and market situation
  - Investigation of suitable areas; criteria for site selection and selection process
  - Storage systems for different power plant technologies
  - Cooling technologies
  - Other fields of application
  - Tendering procedures
  - Operation and maintenance
  - Risk analysis
  - Political framework conditions for CSP
  - Economics of CSP

Note:
...

<table>
<thead>
<tr>
<th>Text Book</th>
<th>Publisher</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Cooling of Buildings (Best (Buildings Energy and Solar Technology))</td>
<td>Routledge</td>
<td>M. Santamouris</td>
</tr>
<tr>
<td>Title</td>
<td>Publisher</td>
<td>Author</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
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<tr>
<td>Solar Cell Technology and Applications</td>
<td>CRC Press</td>
<td>A.R. Jha</td>
</tr>
<tr>
<td>Solar Installations: Practical Applications for the Built Environment</td>
<td>James &amp; James</td>
<td>Lars Andren</td>
</tr>
<tr>
<td>Solar Energy: Fundamentals, Design, Modelling And Applications</td>
<td>Narosa</td>
<td>G.N. Tiwari</td>
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<tr>
<td>Time to Shine: Applications of Solar Energy Technology</td>
<td>Wiley</td>
<td>Michael Grupp</td>
</tr>
<tr>
<td>The Future for Renewable Energy 2: Prospects and Directions</td>
<td>James &amp; James</td>
<td>EUREC</td>
</tr>
<tr>
<td>Thermal Energy Storage: Systems and Applications</td>
<td>Wiley</td>
<td>Ibrahim Dincer</td>
</tr>
<tr>
<td>Flexible Solar Cells</td>
<td>Wiley</td>
<td>Mario Pagliaro</td>
</tr>
<tr>
<td>Solar house: a guide for the solar designer</td>
<td>Elsevier</td>
<td>Terry Galloway</td>
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<tr>
<td>Planning and installing solar thermal systems</td>
<td>DGS</td>
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**Additional references:**

None

**Practical:**

Project oriented teaching recommended. Provide the students with a DEV (develop a solar cooking station for instance).
Annex II
Form for courses’ accreditation
COURSE OUTLINE

<table>
<thead>
<tr>
<th>Course Title:</th>
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<td>Course Coordinator:</td>
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I. COURSE DESCRIPTION

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II. REQUIRED BACKGROUND OR EXPERIENCE

Prerequisites by course:
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Prerequisites by topic:
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2. …………………………………………………………………………………………………………………
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3. …………………………………………………………………………………………………………………
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4. …………………………………………………………………………………………………………………
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6. …………………………………………………………………………………………………………………
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Postrequisites:
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III. EXPECTED OUTCOMES

Students will be expected to develop the following skills/understanding upon the successful completion of the course. They will be able to:
1. ………………………………………………………………………………………………………………………
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2. ………………………………………………………………………………………………………………………
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3. ………………………………………………………………………………………………………………………
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4. ………………………………………………………………………………………………………………………
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5. ………………………………………………………………………………………………………………………
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6. ………………………………………………………………………………………………………………………
………………………………
IV. TEXTBOOK(S) AND READINGS

1. ……………. [Title, Editor, author(s), cost]
2. ……………. [Title, Editor, author(s), cost]
3. ……………. [Title, Editor, author(s), cost]
4. ……………. [Title, Editor, author(s), cost]

VII. COURSE OUTLINE

The following topics will be covered in this course:

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<tr>
<th>Topics</th>
<th>Number of Hours</th>
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