A EUROPEAN M.Sc. COURSE

SOLAR ENERGY: TECHNOLOGY AND *MANAGEMENT*

MODULE SPECIFICATIONS

1. **Module Title: Solar Thermal Engineering**

2. **Credits:** 10 ECTS credits

3. **Keywords:**

Solar collectors, system configuration & simulation: energy storage, efficiency & performance; solar heating, solar air-conditioning, solar thermal engineering applications.

4. **Prerequisites:** Basic Modules I & II
   Co-requisites: Some of the elective modules, such as PV, Wind, Passive Solar Technologies which underpin specializations.

5. **Summary:**

The module contains topics like the solar collector systems for space heating, hot water production, air- conditioning & cooling: Analysis & simulation packages: f-chart, Φ-f chart method & TRNSYS simulations. Thermal Energy Storage Systems: Pebble beds, thermal, ground, phase change, chemical and others. Also, includes the theoretical analysis and testing of solar thermal systems. Efficiency and long-term performance measurements.
A number of practical applications like solar thermal system configurations for various applications. Flat plate and concentrating collectors (systems), solar vacuum, tubes/collectors.
A review of physical-chemical processes for cooling, heating, air-conditioning, water desalination & purification; industrial process heat and solar thermal conversion to Mech. Energy is attempted (Stirling machines).
The solar economics are studied to give figures of merit & economic indicators for energy savings and optimization of size, operation and development of solar thermal systems

6. **Learning Objectives/Skills:**

Upon successful completion of the module the students should be able to:

1. Design a solar flat plate collector system in geometrical, energetical and performance terms to meet the customer requirements.
2. Calculate the performance of the solar collector (systems).

3. Carry out experiments for the thermal performance and measure the efficiency and long-term performance of the solar collector systems.
4. Make theoretical analysis of efficiency and energy gain for flat plate collectors, concentrating collectors, solar ponds and solar vacuum tubes.
5. Design solar collector systems of various configurations and types for small, medium and large-scale applications.
6. Design a solar thermal system (water, air) to meet the energy needs and special requirements for water heating, space heating, air-conditioning, etc.
7. Predict via simulation packages (TRNSYS, f-chart. Φ ~f) the optimal sizing and the configuration of such systems.
8. Couple solar thermal systems to other R.S.E. and heat pumps or passive solar architectures and techniques in order to satisfy customer requirements.
9. Understand and design solar collector systems through a holistic approach, to meet the energy needs via the industrial process heat.
10. Carry out, successfully, case studies for economics, viability and competitiveness, concerning solar thermal engineering.

7.Content/Knowledge Base:

1. Solar flat plate collectors: theoretical analysis, efficiency and long term performance; experimental procedure for testing: ASHRAE 77-93.
2. Inter-connecting solar collectors; installation of solar collector systems for small, medium and large-scale applications: factors to be considered, calculated and measured.
3. Concentrating collectors, overall characteristics; case of non-imaging concentrating collectors and collectors of linear imaging. Thermal analysis and performance. The same for solar ponds and solar vacuum tubes.
4. Measurements of efficiency and performance of the above types of solar collector systems.
5. Solar water heating systems: Design and performance.
6. Solar space heating and storage: ground, water tank, pebble bed, phases changes, chemical etc.
7. Coupling of air-water solar thermal systems to heat pumps & passive systems. Solar desiccant cooling and solar mech. Cooling; optional part.
8. Simulation packages by hour, monthly averages (f-chart). Φ-f, TRNSYS etc Calculations for various cases about energy efficiency of the overall system; considerations of the above issues for concentrating solar collectors, solar ponds, solar vacuum tubes etc.
9. Solar energy applications to the agricultural sector, the domestic and industrial one; also to Civil buildings: Schools. State & private buildings/ offices etc
10. Solar thermal systems for heating spaces, (crop) drying, cooling, etc as appropriate.
11. Review of solar absorption cycles for cooling, air-conditioning. Solar industrial heat process.
12. Economic issues in case studies relevant to this module.

8. Learning Strategies	**Hours**	**Comments**
Lectures	45	
Practical/Laboratories	15	Indoor experiments & field work: see

		issue no.11
Tutorials/Seminars	10	Discussion on various field applications world-wide
Computer Laboratory	20	Use of software in the Lab; and acquaintance with other internationally used packages: see issues no. 11
Student managed learning	110	Work in the reference library and case studies
Total hours	**200**	

9. Assessment	**Weight %**	**Comments**	**Outcomes Tested**
Tests	30	In class with any ref. available	Ability to analyze, calculate, synthesize, compare and assess
Assignments	40	Assignment to each one student a case study on solar collector systems & configurations, efficiency, economics viability, etc.	Dissertation to be delivered by each student. Ability to analyze and innovate on the objectives as in no.6.
Lab work	30	Run various software packages Lab experiments to carry out measurements of efficiency, heat gain, heat storage in solar thermal configurations	Comparison of the results from the various packages. Discussion of the assumptions and the models adopted to simulate the real cases Skills acquired on design innovations and performance of solar thermal collector systems.

10. References:

1. Peter I. Lunde, "Solar Thermal Engineering, Space Heating & Hot Water Systems", I.Wiley & Sons (1980)
2. Duffie, W. Beckman, "Solar Engineering of Thermal Processes", I. Wiley & Sons (1980)
3. D. Yori Goswami, F. Kreith & I. Kreider, "Principles of Solar Engineering", McGraw-Hill Co. (2nd edition) (2000)
4. K. Boer, "Advances in Solar Energy" An annual Review of R & D, vol. 12, ASES (1998)
5. S. Behling, St. Behling & N. Foster , "Sol Power: The Evolution of Solar Architecture" (1996)
6. Ian Graham, "The Solar Power" (1999)
7. Solar Thermal Engineering; A reference book supported by CDs
   S.Kaplanis, TEI Patra
8. Solar Thermal Technology
   B.P. Gupta, Taylor & Francis Inc., 1990
9. Solar Thermal Energy Utilization: German studies on Tech. And Applications
   M.Becker, Springen – Verlag
10. F.Kreith/J.F.K. Kreider, "Principles of Solar Engineering" McGraw Hill Book co 1978

11. J.R. Simonson, “Computing Methods in Solar Heating Design” McMillan Press, London, 1984
12. Solar Collector and Systems Testing Group. A series of proceedings of the meetings coordinated by J.R.C. Ispra E.C. Publications

11.Learning Resources/Support

1. Course material: text books, case studies and reports. A reference Library with books as in no.10
2. Proceedings of Seminars, Conferences, Symposia and Workshops on this domain.
3. Journals: Solar Energy, Renewable Energy, Solar Physics, Solar Energy Materials and Solar Cells, Renewable and Sustainable Energy.
4. Adequate updated software: TRANSYS, f-chat, FEHT-32
5. Site visits
6. Demonstration of solar thermal systems configurations:
7. Concentrating collectors, high temperature ones etc.
8. Solar vacuum tubes: high temperature applications
9. Mounting solar collectors and solar thermal collector systems’ configurations
10. A Test rig for experiments on the efficiency of solar collectors

12. Project thesis, Case studies, Publications, Reviews and other issues related to the module

1. Design and construction of solar collectors systems for heat water production and latest heat storage.
   Final year thesis: TEI Patra
2. Software package for designing solar heating systems Glasgow Caledonian University and T.E.I Patra.
3. Greenhouses with ground heating coupled to solar air heaters. Study and construction project, financed by **EOMMEX** (Greek Organization of small and medium Enterprises) TEI Patra
4. Preliminary results of the use of renewable energy sources in commercial Mediterranean fish hatcheries, International Conference on Ecological Protection of Earth.
   A research project for M.Sc. students coordinated by TEI Patra.
5. Estimation of the uncertainty in the sizing of solar energy systems due to uncertainties in the concept of degree-days in the clearness index: the case of W.Greece.
   A research project at M.Sc. and M.Phil. level by TEI Patra and Anglia Polytechnic University
6. An accurate fast converging iterative technique to determine flat plate solar collector performance and other useful parameters.
   A research project at M.Phil. level by TEI Patra and Anglia University
7. Water purification by forced evaporation via solar collectors coupled to the system of solar skills.
   Final year project: TEI Patra.
8. An automated test rig for the efficiency of solar collectors, monitored and controlled by a micro-processor.
   A final year project: by TEI Patra

9. Design, Construction and Performance tests of two different Solar Domestic Hot Water Systems.
   M.Sc. Thesis: A joint project by TEI Patra and Linkoping University, Sweden.
10. A review of simulation models developed for solar air heaters

A TEI Patra project report