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CONCEPTION OF A MASTER DEGREE PROGRAM IN SOLAR ENERGY: INFRASTRUCTURE, STRUCTURE AND RESULTS

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Abstract

Sustainable development is a key issue for the modern world economy. A solution for reducing the impact of carbon dioxide emissions on climate change and for compensating depletion of conventional energy resources relies on green economy and renewable energy. Polytechnic University Timisoara has a pioneering role in research and applications of solar energy to industrial and residential systems in Romania. The "Renewable Energies - Solar Energy" master program has been introduced for providing a formal framework for environmental education and is dedicated to formation of highly qualified specialists. The program is organized by the Department of Physical Engineering Fundamentals since 2008. We present the motivation, conception, structure and results obtained by running this master program. Competences of graduates include: knowledge of thermal and photovoltaic solar energy chains, innovation in solar technology, assessment of new solar systems, ability to design automated systems for solar energy applications, operation and maintenance of solar systems and installations and management of solar systems. The curriculum and the syllabi have been designed for the creation and development of: cognitive competences, practical and applied skills, management, communication and relational abilities that are useful to the specialist working in the field of Solar Energy in the first half of the XXI century.

Keywords: environmental education, master, solar energy

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1. Introduction

The contemporary fossil fuels-based economy is threatened by depletion of natural resources. Alleged carbon dioxide emissions impact on climate change requires urgent measures for reduction. A widely accepted partial solution to these issues relies on development of renewable energy industries. In the last years, important efforts have been directed towards education of general public for using green solutions and for sustaining the development of the green economy. Classes in schools and courses in universities have been dedicated to environmental education.

Although courses in universities provide some technical expertise in the field, implementation of renewable energy paradigm requires dedicated specialists, like all modern technology fields do. Awareness of this necessity has led to the creation of the "Renewable Energy - Solar Energy" (RESEM) master degree program at the Polytechnic University Timisoara (UPT). In this paper, we present the conception of the master program, the dedicated infrastructure, the educational characteristics and the

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results obtained by running the program for several years.

UPT is a public higher education institution, founded by royal decree under the name “Polytechnic School of Timisoara” in 1920. The current name of the University was established by government decision in 2013. UPT is an education and research institution of national interest and is part of the Romanian university education tradition. UPT contributes to the scientific, professional and civic development of the young generation and to its integration into the economic and social life, to the continuous education of university graduates, and to creation of science and technology.

UPT acts according to the principles of Magna Carta of European Universities and to models of Romanian schools, targeting the free, complete and multilateral development of human individuality and the creation of competent, autonomous and creative professional personalities. The main objectives of UPT are: competitive professional formation of specialists; scientific research and technological development; design, consulting, technical assistance, expertise, control of production quality; education improvement; and service delivery.

Based on the permanent evaluation of education as a process in a complex system, UPT is interested in adjusting its own education and research programs according to the needs of the Romanian society, to the evolution of science, technology and culture, to programs developed by other Romanian and foreign universities and professional organizations and to requirements of national and international accreditation institutions.

The recently created interdisciplinary RESEM master program belongs to the field of Higher Education in Power Engineering. Like all accredited master programs, it is subject of various national regulations and observes the Bologna recommendations. Due to its interdisciplinary character, RESEM is organized by the Independent Department of Physical Engineering Fundamentals (BFI) in conjunction with the departments “Automation and Applied Informatics”, ”Power Engineering”, “Measurements and Optical Electronics" and “Civil Engineering Installations".

The mission of the program is to offer a modern engineering qualification that provides: environmental education and awareness of necessity for sustainable development, knowledge of photovoltaic (PV) conversion and thermal (T) conversion of solar energy, skills in design and technical and economic analysis of automated solar energy systems, as well as competences in innovation and research and in evaluation and assessment of new solar systems. From a European master organization perspective (Davies, 2009), RESEM is situated at the intersection of professional and research masters, since it provides both advanced scientific knowledge and practical competences and skills.

An Internet search showed that several master programs dedicated to Renewable Energy are proposed in Europe and the US. However, we have found only one program dedicated entirely to Solar Energy in Europe, a fact that motivated the present report. The only Solar Energy master program we have found in Europe is proposed by the “Dalarna” University, Borlänge, Sweden (https://www.du.se/en/study-at-du/). This two-year program comprises 120 credits (ECTS) and courses are taught in English. Specializations both in research and development of PV applications as well as T applications are proposed. An important motivation for introducing this master program stemmed from the experience accumulated and results obtained within the Research Center in Solar Energy functioning with Dalarna University.

The credibility of a master program, albeit research or industry oriented, relies on the experience and research results obtained within the institution that proposes that program. The BFI has an extensive experience in Solar Energy research and applications. The first laboratory dedicated to research in Solar Energy in real environmental conditions has been created back in 1976 (Luminosu et al., 2010a). Considering the Romanian context, the work in PV and T conversion of solar energy that has been performed in the laboratory had a pioneering character (Luminosu et al., 2011, 2012). The team involved in Solar Energy has developed theoretical and experimental studies on actinometry, on solar collectors and T conversion of solar energy, on PV conversion systems and on development of diatherman and atherman materials for solar energy applications (Luminosu et al., 2010b).

T systems for melting bitumen in asphalt mixtures stations have been designed (Luminosu et al., 2007a). The resolution of the International Congress "Routes et Dévélopement" held in Vienna, Austria (1984) established the global priority on industrial-scale application of solar energy to bitumen melting in view of use in road construction and civil engineering (De Sabata and Nicoară, 1984).

A PHD school has been organized within the BFI department, which provides opportunities for career development to master program graduates who are interested in research. More than 50 contracts and grants have been carried out and more than 200 scientific papers and 3 books have been published (De Sabata et al., 2010).

In the next Section, we discuss the infrastructure on which RESEM was built in order to illustrate the above mentioned requirement on the credibility of the master degree program from an engineering point of view. In Section 3, we present the competences that RESEM students acquire and the courses that develop these competences. Section 4 details the courses syllabi and results obtained after several years of running the program. Some gathered and calculated data are briefly reported in order to demonstrate the operational capability of the laboratories that have been developed and the opportunities the local climate provide for education in Solar Energy. This also provides a perspective on the modern pedagogical approach from technical and economic points of view. Perspectives are reported in Section 5 and conclusions are drawn in the last Section.

2. Infrastructure: Real Life Laboratories within the BFI

The laboratories and installations that operate in real life conditions are used for research and education. RESEM students are involved in practical training within the Solar House and Educational PV Station. Collected data are also used by students in the Dissertation Theses they elaborate for graduation.

2.1. The Solar House and the energy chain

Solar buildings are equipped with T systems in view of climatization and supply of hot water for domestic use. Since favorable solar conditions and heat demand are not simultaneous, the energy chain must contain the following elements: solar collectors, heat transport pipes, boilers and radiators.

The "Solar House" building is presented in Fig. 1. Collectors are placed on the ground, on a terrace situated in front of the southern wall of the Solar House and on the roof of a neighboring building. A parabolic concentrator is situated on the terrace of the Solar House. The building is equipped with three T circuits. The circuits are composed of: T panel for conversion of solar energy into thermal energy, insulated pipes for heat transfer and boiler for the accumulation and storage of thermal energy as sensible heat. The sensible heat storage material is water. The collecting field consists of seven panels with a variable number of heat pipes, from 12 to 30. The surface of a collector varies between 1.8 and 4.5 m^2. The volumes of the boilers range between 100 and 250 liters (Fig. 2). Power ranges from 1800 to 4500 W depending on the surface of the panels. Annual savings of natural gas vary between 1440 and 2400 m^3/year.

Fig. 1. Solar House

2.3. Educational PV system

Solar systems based on PV panels are advantageous because the number of intermediate links between the primary source and the user is small and therefore total energy losses in intermediate links of the energy chain are reduced. The educational PV installation is equipped with solar cells that cover a surface of 14.85 m^2. The total surface of the panels is 16.72 m^2. The produced energy is supplied to a consumer situated in one of the Physics Laboratories and the excess energy is injected into the national electricity grid (Toader et al., 2012).

The schematic diagram of the experimental system is shown in Fig. 3: PV panels - 1 batteries - 2, inverter - 3, local consumer - 4, monitor and on-line database - 5. The panels are facing south and are tilted by 45 degrees. Collected data are stored and can be made available on-line in view of reference for institutions and private entities and persons interested in assessment of solar energy installations in the region. A photograph of the PV system is presented in Fig. 4. The panels are installed on the terrace of the building where the BFI department is located.

(a)

(b)

Fig. 2. Boiler with hot water accumulation (a) and solar collector used in student activities (b)

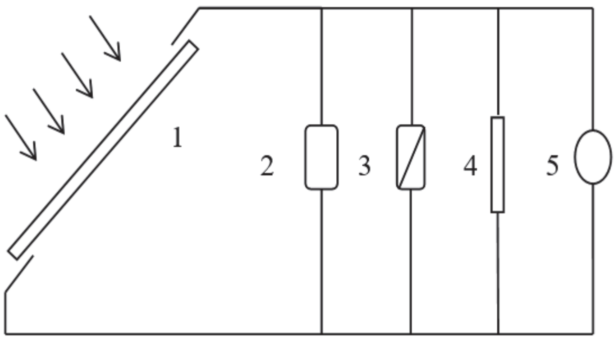


Fig. 3. Schematic diagram of the PV system

Fig. 4. Panels of the PV system

2.5. Research Institute for Renewable Energies

In the near future students will be able to carry out further practical works and training within the facilities provided by the Research Institute for Renewable Energies (ICER), a UPT subsidiary built with European funding, Fig. 5. The headquarters of the Institute are located in an energy-independent building, which is equipped with thermal solar plants (Fig. 5a), solar panels (Fig. 5b) and biogas installations.

3. Competences Acquired by RESEM Graduates

The formation of specialists in new areas of knowledge and technology is required by the economic and technical issues of the beginning of the XXIst century. The increase of the price of energy, resources exhaustion and climate change determine both individuals and public entities to rely on renewable sources. Solar Energy is a feasible, clean, free, unlimited solution for many domestic and industrial applications such as: climatization, drying, distillation, heating with solar ovens for production of new materials with superior properties, generation of electricity for remote and isolated settlements, water supply etc.

The UPT research policy is targeted, among others, to integration into programs initiated at European level. Since RESEM prepares specialists able to respond to European challenges raised by the energy of the future and by the sustainable development, its aims are correlated with the educational and research priorities of the university.

The theoretical and applied studies performed by students within RESEM allow for acquiring cognitive and intellectual capacities, practical skills and communication abilities.

The cognitive capacities are related to:

- understanding the positive impact of non-conventional energies on quality of life, ambience, sustainable development and conventional sources of energy;
- understanding and use of physical phenomena involved in solar energy conversion into other forms of energy;
- knowledge of the norms and standards related to solar buildings;
- understanding and application of principles of management of solar facilities.

General cognitive competences are assured by the following courses: *Renewable Energy*, *Physics of Solar Energy* and *Measurement Data Acquisition and Processing*.

(a) (b)

Fig. 5. Part of ICER headquarters with (a) thermal solar plant and (b) PV panels

Practical skills include:

- knowledge of T and PV energy chains in view of design and equipment of social, industrial and residential buildings;
- capacity of innovation, study and evaluation of new solar systems;
- ability to design automation systems for solar energy installations;
- assessment, operation and maintenance of solar installations.

Disciplines that provide formative skills are: *Physics of T Conversion*, *Optical Electronics* and *Physics of PV Conversion*. Expertise and practical and applied competences are offered by the following disciplines: *T Systems*, *PV Systems*, *Equipment for Solar Constructions*, *Automation of T Systems*, *Automation of PV Systems*.

Communication and relational abilities refer to:

- dissemination of results concerning studies on phenomena involved in the conversion of solar energy and application of energy generated by solar means in the scientific and technical communities;
- transmission of knowledge and creation of skills for successive generations of students;
- capacity to exploit the products of an economic agent;
- capacity of attracting funding and investments for a specific target;
- dissemination of knowledge and practical experience related to T and PV systems in the general public in view of environmental education.

Communication and professional skills (Mohan et al., 2010) are developed in two psycho-pedagogical facultative modules sustained by the specialized department of UPT. Management capacity of new energy sources and facilities is acquired from the course of *Management of Solar Buildings*. Awareness of the need for an ecological attitude of the European specialist is formed at the disciplines: *Elements of Solar Architecture* and *Solar Construction Equipment*.

4. Syllabi

RESEM is organized in the context of the Bologna paradigm. We briefly describe the syllabi of the disciplines and the associated number of ECTS points. The RESEM curriculum includes compulsory, optional and facultative courses. Following the selected optional topics, the student is able to follow either the PV or the T path. Pedagogical courses enable graduates to pursue a teaching career.

The disciplines are spread across three semesters. The fourth semester is dedicated to research and conception of the dissertation thesis. A total of 120 ECTS credit points (cp) are assigned to graduates. Teaching activities include lectures (l.), practical activities in laboratory (p.) and projects (d.)

4.1. Physics and Use of Solar Energy - 1st semester, 8 cp, 28 h l., 28 h p

1. The Sun as a cosmic body 2. Astronomical coordinate systems used in solar energy 3. Generation of solar energy through thermonuclear fusion phenomena: principles and fundamental laws, quantities and units 4. Interaction of solar radiation with the atmosphere and the ground.

4.2. Renewable Energy - 1st semester, 7 cp, 28 h l., 14 h p

1. The current global energy situation 2. Hydropower 3. Wave energy 4. Wind energy 5. Solar Energy 6. Geothermal energy 7. Biomass 8. Hydrogen Energy and Fuel Cells 9. Magnetohidrodinamic conversion 10. Special topics in conversion technologies.

4.3. Acquisition and Processing of Measurement Data - 1st semester, 8cp, 28 h l., 14 h p

1. Structure of a measurement system. Measurement principles and methods for solar irradiance, electric and thermal energy, and solar panels parameters 2. Analog to digital converters 3. Communication standards for transmission of measured data. Interfaces. 4. Measurement data processing (analog and digital filtering, adaptive filtering, time-frequency conversion; interpolation and prediction methods).

4.4. Physics of T Conversion - 1st Semester, optional, 7cp, 28 h l., 14 h p

1. Elements of reversible and irreversible thermodynamic processes. 2. Characteristics of solar radiation. 3. Conversion of solar energy into heat within conversion systems; 4.T conversion 5. Storage and accumulation of solar energy 6. Energy T chain 7. Solar furnaces 8. Economic and environmental aspects of T conversion.

4.5. Physics of PV Conversion - 1st Semester, optional, 7cp, 28 h l., 14 h p

1. Fundamentals of quantum physics; 2. Quantum physics formalism; 3. Applications of Schrödinger's equation; 4. Quantum statistics; 5. The crystalline structure of matter; 6. Properties of crystalline solids; 7. Elements of Semiconductor Physics; 8. Diodes; 9. Contact phenomena; 10. Elements of Optics; 11. Interaction radiation - matter; 12. PV conversion.

4.6. PV Systems (1)-2nd Semester, and (2) - 3rd semester, optional, both with 7cp, 28 h l., 14 h p./14 h d

1. PV conversion; 2. Solar cells; 3. Models for

solar cells; 4. PV components and systems; 5. The PV generator; 6. Functional system testing; 7. Sizing of PV systems; 8. Elements of financial analysis and of the PV market; 9. PV systems in Romania.

4.7. Thermal Solar (T) Systems (1) - 2nd Semester, and (2) - 3rd semester, both with 8cp, 28 h l., 14 h p./14 h d

1. Solar radiation at ground level; 2. T energy chain; 3. Controllable variables of the T collector; 4. Thermodynamic analysis of solar collectors; 5. T systems in industrial applications; 6. T systems in home applications; 7. T systems in the EU countries; 8. Design of T installations; Norms and standards; 9. Economic and environmental aspects.

4.8. Optical Electronics - 2nd semester, 7cp, 28 h l., 14 h p

1. Spectrum of light, vector and scalar wave Optics; 2. Photometric quantities; black and grey body radiation; diffuse and specular reflection 3. Semiconductors, the pn junction: emission and absorption of light; LED; applications; 4. Photodetectors: photodiode, phototransistor; applications; 5. PV cells and panels; 6. PV applications of optoelectronic devices; 7. Lasers. Semiconductor lasers. Applications.

4.9. Automation in PV or T systems - optional, 2nd Semester, 7cp, 28 l., 14 p., 14 d

1. Elements of system theory and mathematical modeling; 2. Control systems; 3. PV/T conversion process as an automatic system; 4. Measuring instruments and specific execution elements; 5. Digital control and devices; 6. PV/T automation systems for home applications; 7. Management of distributed PV/T systems; 8. Economics.

4.10. Solar Construction Equipment - 3rd Semester, 7cp, 28 h l., 14 h d.

1. Types of energy; 2. Solar energy as a heat source; 3. Solar hot water installations; 4. Solar heating installations (active and passive); 5. Calculation of active heating installations; 6. Solar cooling; 7. Solar power plants.

4.11. Solar Buildings Management - 3rd Semester, 8cp, 28 h l., 14 h d.

1. Current state in the use of individual solar installations; 2. Techniques, use and conversion of Solar Energy; 3. Problems in using electricity derived from solar energy; 4. Operating modes of solar installations; 5. Methods of storage of the energy produced by solar plants; 6. Energy management systems in buildings; Market supply; 7. Regulations for grid-connected systems; 8. Evaluation of technical feasibility of solar installations; 9. Economic feasibility assessment; 10. The concept of integrated energy hub.

4.12. Elements of solar architecture - 3rd Semester, 8cp, 28 h l., 14 h d

1. Ecology, a priority of the XXI century; 2. Principles of ecological residences; 3. Passive solar residences and the greenhouse effect; 4. Active solar houses; 5. PV Architecture; 6. Intelligent Buildings; 7. Efficient insulation systems for buildings; 8. Natural lighting; 9. Conclusions.

A number of 15 cp is assigned to 98 h of practical training and research in the fourth Semester. An equal number of credit points and working hours are assigned to elaboration of the dissertation thesis, also in the last Semester. Several published books (Popov and Pop, 2010, Luminosu, 2007b, Paulescu, 2005) and on-line lecture notes on the faculty's websites are available as learning support.

5. Experimental results obtained by students

As a case study of practical activities, we present measurement results obtained by students on September 9, 2012, in the hourly interval 8 -17 for the T system. Fig. 6 shows the irradiance on the collecting plane. At noon, irradiance reached 900 W/m^2.

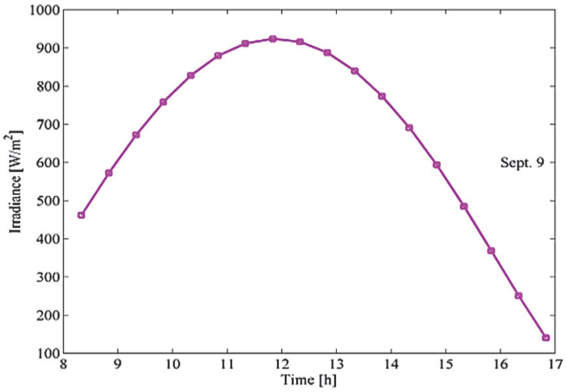


Fig. 6. Solar flux density in the collecting plane

Fig. 7 displays the temperatures at the collectors output, in the storage tank and the ambient one. At 17 hours the heating process stopped because the output collector temperature and the temperature in the storage tank tended to equalize.

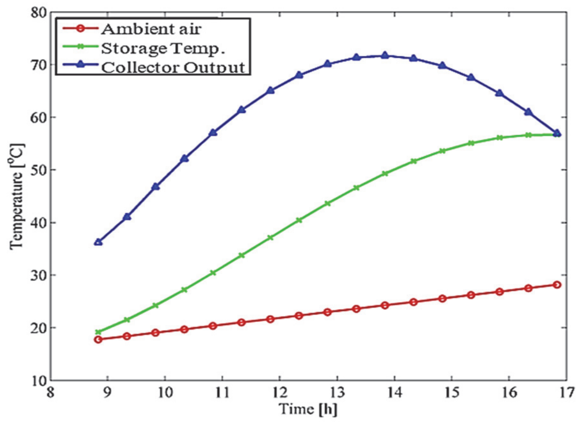


Fig. 7. Temperatures in the energy chain links

The collector temperature and system efficiencies are calculated according to well established procedures (Luminosu and Marcu, 2003; Tiwari, 2006) and are reported in Fig. 8. At the initial moment, a 62% collector efficiency and a 48% installation efficiency have been measured. The efficiencies decreased towards zero at 17h.

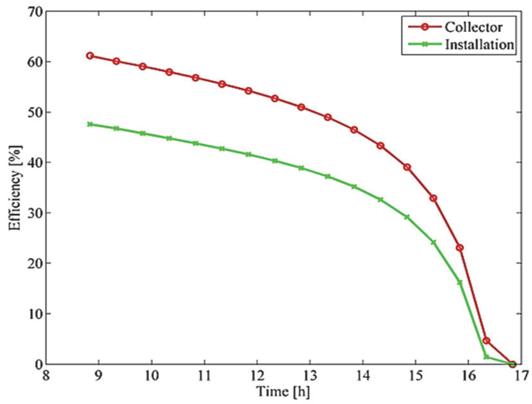


Fig. 8. Efficiencies of collectors and installations

A friendly attitude to environment requires, among others, reduction of carbon dioxide emissions. Students estimate the reduction of carbon dioxide emissions when gas based heating is replaced by solar panels as outlined below.

Calculations performed by students according to (Fara et al., 1991; Grec et al., 2012; De Sabata et al., 2014) show that the mass of carbon dioxide that is not emitted in the atmosphere (spared) is $m_{y,D,T} = 120.48\,\mathrm{kg/m^2 \cdot year}$ (D - dioxide, T - thermal, y - annual).

The exergy ES received from the Sun, the useful exergy EB in the boiler, the exergy efficiency ε and the average exergy efficiency ε_m are calculated according to (Zamfirescu and Dincer, 2009). Results obtained by students for the segment with a collecting area of 6 m^2 and boiler with a volume of 200 l are reported in Table 1.

Students perform measurements in the context of practical training associated to the *PV Systems* discipline. The following primary quantities are measured: solar flux density (irradiance) G (W/m^2), ambient temperature T (°C), voltage at panel terminals U (V), and output current I (A). Secondary physical quantities are determined by calculation: incident solar power $P_{inc} = G \cdot A_{C,PV}$, output power $P_u = UI$, and efficiency $\eta = P_u/P_{inc}$. The incident power and the efficiency are calculated in two ways: by considering the total area of the cells (P_{inc}) and the total area of the panels ($P_{inc,p}$). Solar flux density and ambient temperature are measured with a Kipp-Zonen pyranometer and a Pt100 transducer based thermometer. The obtained values are compared with data extracted from the online database provided by the West University of Timisoara (Paulescu et al. 2010; Jurca et al., 2011). Experimental data gathered in June 22, 2012 are reported in Table 2. The efficiencies of the panels vary between 12 and 14%.

Students estimate the reduction of carbon dioxide emissions that result from the substitution of natural gas based electricity production with a PV panel based one (Fara et al., 1991; Grec et al., 2012). The contribution of the unit surface of collecting area to carbon dioxide reduction is $m_{y,D,PV} = 102.94\,\mathrm{kg/m^2 \cdot year}$.

Table 1. Exergy ES received from the Sun, useful exergy EB in the boiler, exergy efficiency ε and average exergy efficiency ε_m

Hourly Interval	***8-9***	***9-10***	***10-11***	***11-12***	***12-13***	***13-14***	***14-15***	***15-16***	***16-17***
ES [MJ]	9.72	13.61	17.28	19.22	18.58	15.56	12.31	8.86	4.32
EB [MJ]	0.0007	0.025	0.096	0.117	0.375	0.529	0.281	0.149	0.070
ε [%]	0.007	0.18	0.56	0.61	2.02	3.39	2.28	1.68	1.62
ε_m [%]	1.37								

Table 2. Incident power, output power, and efficiency of PV panel at September 16, 2011

Hour	***G (W/m²)***	***P_u(kW)***	***T(°C)***	***P_{inc}(kW)***	***$P_{inc,p}$(kW)***	***η (%)***	***η_p[%]***
7:00 AM	27.9	0.04	19.2	0.41	0.47	10	9
8:00 AM	205.7	0.41	19.6	3.05	3.44	13	12
9:00 AM	447.3	0.96	21.2	6.64	7.48	14	13
10:00 AM	675.9	1.4	23.1	10.04	11.30	14	12
11:00 AM	849.2	1.68	25.4	12.61	14.20	13	12
12:00 AM	960.5	1.86	28.4	14.26	16.06	13	12
1:00 PM	995.5	1.9	31	14.78	16.64	13	11
2:00 PM	927.7	1.79	31.9	13.78	15.51	13	12
3:00 PM	803.6	1.59	32.2	11.93	13.44	13	12
4:00 PM	611.2	1.24	31.9	9.08	10.22	14	12
5:00 PM	376.8	0.77	31.6	5.60	6.30	14	12
6:00 PM	139.8	0.27	29.4	2.08	2.34	13	12
7:00 PM	19.5	0.02	26.6	0.29	0.33	7	6
8:00 PM	3.4	0	25	0.05	0.06	0	0

RESEM students perform other practical training activities in UPT laboratories within the partner entities: Physics, Automation, Optical Electronics, Civil Engineering etc. Evolving successfully on the energy market requires a solid economic background. Based on information and measurement results obtained by operating the experimental PV and T stations, engineering students have the occasion to apply their theoretical knowledge of Economics to assessing of financial efficiency of solar installations (De Sabata et al., 2014, Kalogirou, 2009; Lo et al. 1994; Messenger and Ventre, 2004; Whisnant et al., 2003; Zamfirescu et al. 2012).

Fig. 9 shows that the profit obtained from PV investments can be smaller than the net annual discount rate, or even negative, for quite small values of loan interests. Therefore, tax deductions, green certificates and other incentives must be introduced in order to make solar green electricity interesting for investors (*i* - interest rate).

The profit obtained by investing in the PV produced energy, as displayed by Fig. 9, pleads against the feasibility of the project (the percent profit is very low (Tiwari, 2006)). A similar simple analysis can be performed for T systems. The profit versus loan reimbursement time *n* is represented in Fig. 9 for several values of the interest rate *i*. Economic analysis results indicate feasibility and a better economic performance for T systems than for PV systems.

6. Social perspectives

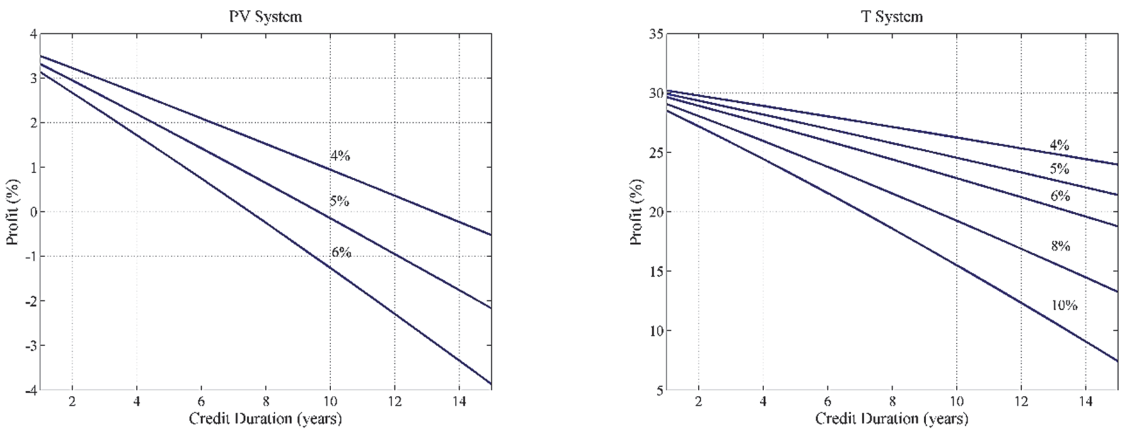
Prospects of RESEM arise from the evolution in the energy sector at national, European and global levels. We recall that the EU share of energy from unconventional sources will reach 20% of overall energy production by 2020. A 20% reduction of carbon dioxide emissions and energy savings of 20% based on energy efficiency are also provisioned. Such issues are addressed in the master program.

In the near future technical and economic conditions, RESEM graduates will be absorbed by the labor market in the following segments:

- production of highly automated solar equipment;
- development and production of materials with superior properties;
- energy-efficient buildings;
- design of high efficiency solar installations for both new constructions and energy rehabilitated buildings;
- operation and maintenance of solar systems;
- feasibility studies of various solar systems;
- management of solar systems;
- education.

Competences, skills and abilities accumulated and developed in the solar energy master school are a preparation for the next step: the doctoral school. Areas in which the University conducts doctoral specializations relevant for the RESEM graduates are: Automation, Power Engineering, Electronics and Civil Engineering. The first generation of students enrolled for RESEM started in 2008 and graduated in 2010.

Several student achievements are worth to be mentioned. Examples of well realized dissertation theses are: "Numerical Study of thermo elasticity in detached solidification of InSb and GaSb" (developed in cooperation with SIMAP laboratory - EPM in Grenoble, France), "Experimental Study of the solidification interface and the grain structure in photovoltaic Si", "Independent energy systems for a holiday home using solar panels, wind turbine and hydro turbine", "Caption and storage of solar energy", "Sizing of PV systems", "Performance evaluation of grid-connected PV systems". Internationalization is an important aspect of modern European master programs (Davies, 2009, Stoiciu et al, 2012). Therefore, actions have been attempted by the board of the master program for fulfilling this goal. As a result, two graduates beneficiated of scholarships in France in view of preparation of their dissertation theses, and were subsequently admitted to the Grenoble University for a PhD program.



(a) (b)

Fig. 9. Estimated profit of PV and T systems within UPT versus credit duration for several values of the interest rate for (a) PV system and (b) T system.

Higher qualification themes by PhD school at the Grenoble University are: "Numerical and experimental studies of magnetic effects on solidification of metallurgical silicon for PV applications" and "Conception du réseau de bord d'un camion tout électrique".

In addition to the prospects for carrier development through research, master graduates have good employment opportunities in solar energy industries in the western region of Romania and all over the country. The solar industry is already growing and its future evolution is favorable not only due to the established European directives, but also due to the favorable solar potential in the region, highlighted by several independent studies (PHARE Program, 2006).

7. Conclusions

A master program in Solar Energy has been developed within UPT, motivated by contemporary trends in energy production and management coherent with sustainable development. A demonstrated favorable solar potential of the region is another supporting motivation. The primary goal of the master program has been to raise environmental education to superior technical and scientific levels.

The curriculum and syllabi have been conceived according to the necessity to respond to the commandments of the Bologna Declaration, namely development of competences and abilities, student centered learning and internationalization.

Graduates of the RESEM acquire skills that are needed for developing new technologies in the renewable energy sector. They possess intellectual capacities, moral and cognitive abilities that create the premise for responding constructively to the challenges relative to an advanced economy and sustainable development in the new millennium.

Acknowledgements

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