Integration of Knowledge of Solar Thermal and Solar PV Technologies in Physics Education for Enhancing Skill Development

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Abstract- *The world is making a transition towards clean energy choices and for this solar energy is a promising option which is growing at a tremendous rate. In order to combat the global warming and climate change, many countries especially India has set ambitious targets for next 20-30 years focusing on increasing the use of solar energy for various applications. As solar PV and thermal technologies are growing and penetrating in the everyday life applications, it becomes important to make these a part of physics education. Understanding of these technologies by a physics student will offer opportunities for skill development, innovation and research. Department of Pure and Applied Physics, University of Kota offers courses and special paper related to Energy Studies and more specifically Solar Energy. The present work discusses the integration of the knowledge of solar energy technologies in the physics curriculum both in theory and experiments. Further the experience of the Higher Education Partnership Project on Solar Energy Materials and Technologies awarded to the University of Kota by the Royal Academy of Engineering, UK and FICCI, India is also shared. The studies related to solar energy applications enhanced the knowledge of heat transfer, thermal physics, electrical and electronics which in turn results in skill development and opportunities for innovation.*

Keywords**:** Solar Education, Physics education, solar thermal, solar PV, skill development.

Introduction

Majority of the developing countries of the world are situated in the regions which receive more than 5 kWh/m^2 of global solar irradiation per day. Solar energy resource can be used for a variety of applications such as power generation, cooking, drying, water heating, space heating etc. In order to combat the global warming and climate change, many countries especially India has set ambitious targets for next 20-30 years focusing on increasing the use of solar energy. Utilization of solar energy resource can contribute towards social and economic development of communities without adversely impacting climate change but for the successful implementation and running of the solar energy projects it is important that skills should be developed at grass root level [Terrapon-Pfaff 2014, Dóci2015 and Bossink 2017]. Integration of knowledge of solar energy technologies both at the school and higher education level can help in enhancing the awareness and penetration of different solar systems into the society. Inclusion of solar energy

education in technical courses in higher education may provide the deeper understanding of the solar energy technologies, enhance the research and development, and produce innovations for use of solar energy to solve local problems [Sengar et.al. 2017].

Several efforts are being taken worldwide in different institutes to integrate some solar technology knowledge with the physics education such as know-how of solar water heater (Torres 2014), solar radiation (Downs et.al. 2016), organic solar cells (Csernovszky and Horváth 2018), solar energy processes (Măntescu et.al. 2017), elementary concepts of solar energy (Hidirovich, 2021), etc. Recent innovations in solar energy education and research for sustainable development have been discussed at length by R. Senthil (Senthil 2022).

The basic principles and fundamentals of the solar photovoltaic (PV) and solar thermal technologies are strongly linked to the various branches of physics such as thermodynamics, heat transfer, electronics, electrical, solid state and material physics etc. Therefore for physics students knowledge of the solar PVand solar thermal technologies is beneficial from both the ends- on one hand it helps them understand the significance of study of physics in daily life applications in form of solar energy and on the other hand they learn the skills related to solar energy technologies. The present work discusses the integration of the knowledge of solar energy technologies in the physics curriculum both in theory and experiments. Further the experience of the Higher Education Partnership Project on Solar Energy Materials and Technologies awarded to the University of Kota by the Royal Academy of Engineering, UK and FICCI, India is also shared.

Methodology

Department of Pure and Applied Physics, University of Kota offers courses B.Sc. Hons. Physics, M.Sc. Physics and M.Tech. Solar Energy. B.Sc. Hons. and M.Sc. courses have theory papers covering Energy Studies and renewable energy conversion with 2-3 units focusing on solar radiation, solar PV and solar thermal fundamentals. M.Tech. Solar Energy is a complete scientific course based on in-depth knowledge of solar energy area covering different aspects such as solar radiation, solar collectors, solar photovoltaics, solar power generation, solar passive architecture, energy audit and management, modelling, simulation and decision making.

For integrating the knowledge of the solar PV and solar thermal technologies in physics education, following methods are being adopted at the Department of Pure and Applied Physics, University of Kota

Specialized papers and courses – Special paper as Energy Studies form part of the syllabus of M.Sc. Physics, complete course M.Tech. Solar Energy focused on solar energy technologies is being run.

Theory papers – Theoretical papers with units consisting of knowledge of solar radiation, solar thermal and solar PV is introduced in B.Sc. Hons. Physics course.

Experiments – At B.Sc. levels simple experiments related to solar cell I-V characteristic curve, fill factor and efficiency estimation are carried out. At M.Sc. and M.Tech. level there are advanced experiments related to solar cells, solar panels combinations, shading, radiation level variation, computations for solar radiation geometry angles, study of solar collectors and concentrators etc.

Seminars – Students are encouraged to present seminars on various applications and developments in the field of solar energy.

Projects – M.Sc. and M. Tech. students undertake short research projects on the different topics linked to the solar energy technologies.

Visits – Visits to different sites and solar energy research institutes is organized to get the students acquainted with the solar energy technologies and interact with the experts working in the field

Workshops – From time to time several workshops are organized with keynote speakers and experts from India and abroad to share their experience with the students.

Newton- Bhabha Higher Education Partnership Project on solar energy technologies was awarded and carried out at the University of Kota in collaboration with Cranfield University, UK, Durham University UK and industry partner MSA Renewtech, Vadodara, India. The project focused on interactions between the partnering organizations, exchange of knowledge and carrying out several minor student research projects under the guidance of the partners. The knowledge exchange resulted into the revision of the curriculum, skill development of the students and motivated students to pursue research and entrepreneurship in the field of solar energy.

Results and analysis

The solar thermal theory, experiments and projects gave insight to the students about greenhouse effect of glass, transmittance, reflectance and absorbance of different materials. The students learned about beam, diffuse and global solar radiation, computed the solar radiation angles and plotted them with solar time. Optical and thermal properties of materials were easily grasped in a simple manner through working on solar collectors. Solar PV theory and experiments provided the students with comprehensive knowledge of principle, design and working of different types of solar cells, solar modules, losses and measures to improve efficiency.

A number of concepts were learnt by the physics students with integration of solar energy technology knowledge in theory and experiments such as

- Solar Radiation properties, solar energy angles, apparent motion of sun
- Solar radiation spectrum, components, solar constant
- Heat transfer-conduction, convection, radiation

- Thermal conductivity and diffusivity of materials
- Green house property of glass
- Transmittance, reflectance and absorbance of materials
- Absorber coatings
- Solar thermal applications- solar cookers, solar water heaters, power generation, space heating/cooling, refrigeration etc.
- Flat plate collectors, concentrating collectors
- Semiconductors, insulators and conductors
- Solar cells materials, band gap and solar radiation
- Solar cells, modules and panel fabrication process
- I-V characteristics, fill factor, efficiency, maximum power point
- Electrical, optical and recombination losses in solar cells
- Solar PV applications-power generation, water pumping, solar street lights, lanterns and small devices

The integration of knowledge of solar thermal and solar PV technologies resulted in use of concepts of physics in applied solar field and practical hands-on experience through student projects. For enhancement of teaching and research, instead of a single research project, many student research projects focusing on providing a solution to some regional/community level problem through use of solar energy were carried out. Several solar based systems were designed and developed through use of mainly locally available materials which were tested on-field and economic analysis was carried out. Some of the student research projects carried out were

- Design and development of solar induction cooker
- Design and development of solar air cooler
- Design and development of solar dryer
- Design and study of solar hybrid incubator
- Design and development of solar stills
- Study of small size solar water heater for dyeing application
- Study of solar stills with different absorber coatings
- Study of dust accumulation on transparent surfaces and PV panels for Kota
- Study of potential of Organic Rankine Cycle
- Design and development of solar tea stall
- Study of concentrating solar collectors for hot water applications
- Study of heat transfer fluid with parabolic troughs for thermal performance
- Study of waste water treatment through solar
- Estimating auxiliary energy requirement for solar thermal systems
- Operation and maintenance of MW size solar PV systems
- Designing cleaning and cooling method for PV panel, etc.

These projects focused on the regional problem such as dust, heating of PV panels etc. The systems have been developed after analyzing the requirement of the lower and middle income households and cottage industries of developing countries like India, which face the problem of availability of fuel in adequate amount and pollution due to solid fuel use. Commercially available large size water heaters are not affordable and not required for cottage industry of Kota-Doria as they require small size solar water heater for dyeing, so this particular project was taken up. The payback periods for the developed solar induction cooker and solar air cooler were high due to the recurring cost of battery replacement. Thus, these projects were able to convey useful information related to user needs, technological limitations and economics such as payback periods. The theoretical and experimental knowledge prepared the students to think critically in innovative manner and inculcated research interest for socially useful works.

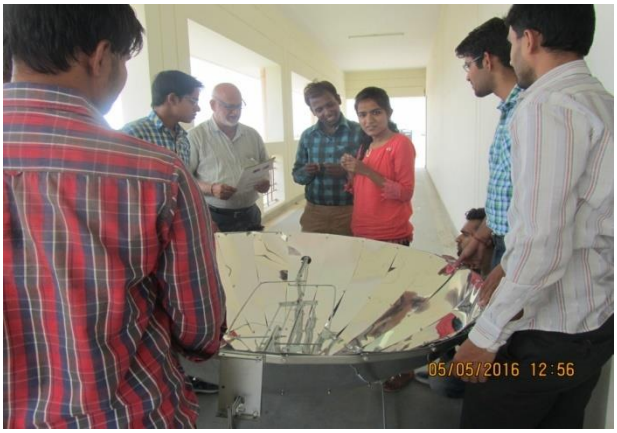

Fig.1 Fabrication of parabolic solar cooker by the students under the guidance

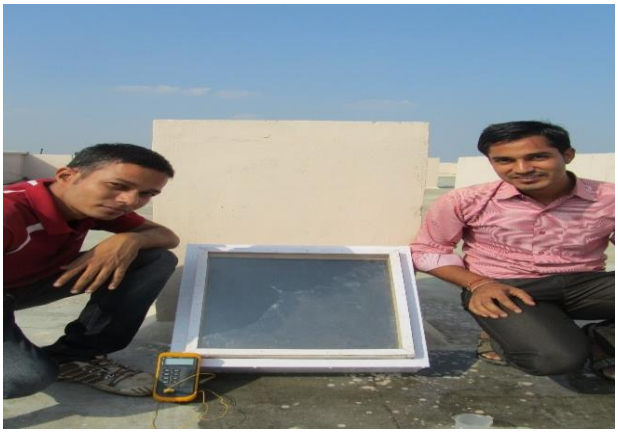

Fig. 2 Developed small size solar water heater for cottage textile industry application

Conclusions

Present work shows that the integration of solar technology knowledge with physics education can help students relate many physics concepts to the applications and lead to skill development and research orientation for society useful innovations. Knowledge of solar energy technologies can be easily integrated into the physics education through theory, experiments, student projects, seminars, visits and workshops as discussed in the present work. Solar PV and thermal technologies are closely related to physics principles and many physicists worldwide are working to improve these technologies. As it is a growing field, physics students should be given a chance to know about the developments and advancements in the solar energy area. There are ample opportunities for research and development in the field of solar energy materials, devices and applications. This integration of physics education with solar energy technology knowledge will keep the physics students update and abreast with the new developments and open new pathways of opportunities for them through skill development.

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