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Activities in Renewable Energy for School Children

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Abstract
Renewable energy education is an important aspect when developing renewable energy. This applies to school level, university level, technical and mechanical training, educating policy makers, project developers, educators, and common public. In this report, we discuss the importance of laboratory work when teaching renewable energy. We have also included a large number of examples in renewable energy school activities are presented.

Keywords
Renewable energy, education, laboratory work, course development. school activities

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1. Introduction:

Fossil fuel scarcity and consequent energy security concerns as well as increasing macro- as well as micro-level adverse impacts of fossil fuel based energy supply have necessitated development and large scale deployment of renewable energy technologies. Any strategy for increasing the acceptance and dissemination of renewable energy technologies should involve all stakeholders – policy makers, researchers, engineers, technicians, mechanics, manufacturers, distributors, suppliers, installers and potential users (common masses) etc. In other words, development and dissemination of new and appropriate technologies for harnessing renewable sources of energy would require a variety of inputs and contributions from all sections of the society and constituents of the economy. In view of the fact that, in many respects, the renewable energy technologies are still emerging, the children of today i.e. decision makers of tomorrow, are likely to play a prominent role in their development and large scale dissemination. An attempt to actively and suitably involve school going children in any strategy towards development and deployment of renewable energy technologies is also expected to have spin-off benefits in terms of direct as well as indirect involvement of their parents/guardians, relatives, friends and other members of the society. Of course, such an initiative also contributes towards awareness generation and also towards preparing them to accept required changes in their lifestyles, in case necessary for use of available options based on renewable energy besides contributing to the operational requirements of such systems. Most importantly, an early exposure to various options for meeting energy demand of the society and an opportunity to realistically assess the potential and importance of harnessing renewable sources of energy could very well ignite and prepare young minds to develop and adopt sustainable energy supply solutions as professionals as well as end-users of energy.

The share of renewable energy sources in the global energy supply is increasing [1]. By the end of December 2014 over 650GW of installed electricity generation capacity in the world was based on renewable sources of energy excluding hydro [2]. It is now acknowledged that the pace of harnessing renewable sources of energy should increase so as to address a large variety of global concerns that include climate change and long term sustainability of energy supply for mankind [3]. In addition, there is an urgent need to identify desirable changes in the lifestyle of humans and their choices of equipment and gadgets so as to ensure long term sustainability of the ecosystem. A conscious attempt should be made to make human beings on the planet cognizant of the all-pervasive role of energy in the economy and also of the consequences of the choices of various energy resource–technology combinations made for satisfaction of energy demand. It is also necessary to make them aware of alternative options and also to involve them as stakeholders in entire process of transition from a fossil fuel based to a predominantly renewable energy based society.

There is some evidence indicating that the exposure, knowledge and understanding gained by children at school level has considerable impact on the behavior and choices made by them as individuals as well as professionals with regard to energy resources and technologies. It has been reported that usually such an exposure makes the person more responsive to the global requirements and the need to adopt appropriate measures accordingly. It would be interesting to undertake more studies in this regard so as to study the behavior of school children that are exposed to various adverse aspects of using fossil fuels, need for energy conservation and harnessing of renewable sources of energy and compare the same with those who did not get such an opportunity. Of course, it would also depend upon the overall societal awareness and broad choices and decisions made at community level. On a broader level, providing an opportunity to the school going children to study renewable energy related topics is expected to result in multiple benefits.

Renewable energy resources can be characterized by their ability to be regenerated at a rate faster than their rate of consumption. Moreover, except biomass energy, all renewable sources of energy do not involve combustion and thus do not produce atmospheric pollutants while being harnessed for delivering energy. Renewable sources of energy are more equitably distributed across all geographical reasons of the world as compared to the distribution of fossil fuels. Thus it may be possible and advantageous for the humanity to develop a low carbon society based on renewable sources of energy. However, the cost of harnessing renewable sources of energy (often compared in terms of leveled cost) for meeting the demand of a specific end use could be relatively higher than the cost of meeting the same demand using fossil fuels. Lack of internalization of various externalities in pricing fossil fuel based energy supply options is an important reason for the apparently higher cost of energy supply based on renewable energy sources. Moreover, it is also necessary to further improve the design and performance characteristics of renewable energy technologies to ensure their competitiveness with energy supply options based on fossil fuels. For the much needed transition to low carbon (green) options of energy supply, it is therefore necessary that concerted efforts are made by all stakeholders on all facets including resource availability assessment, appropriate technology development, techno-economic appraisal/evaluation, demonstration and feedback collection, quality control, after-sales back up, financing etc. Availability of competent manpower in adequate numbers would, therefore, be the key to the success of any strategy towards promoting

large scale utilization of renewable energy technologies. Renewable energy education and training, therefore assumes unequivocal importance in the country. In the long run, with cognizance of the importance of promoting an energy conscious society, it would be necessary to establish effective networks of policy makers, researchers, educators, students, entrepreneurs etc. based on efficient and effective renewable energy education programmes.

The need for efficient and effective means of imparting renewable energy education at all levels and to all sections of the society has long been recognized [4-6]. Considerable progress has already been made in this direction in many countries of the world and continued efforts are necessary to ensure that all countries of the world are able to prioritize the same so as to formulate and implement strategies in this regard. Developing countries of the world that are currently on a rapidly increasing energy demand curve need be more careful in this regard as the energy sector choices made by them would have far reaching consequences for the entire planet. Many of these countries have significantly large potential to leap frog in terms of energy supply mix and thus need not follow the fossil fuel intensive route to growth and development. Instead the energy supply can be made environmentally sustainable and yet affordable for poorest of the poor in the country. Large scale harnessing of renewable energy resources is expected to play a pre-dominant role in any such strategy. One of the important requirements towards making the much needed transition to a renewable energy based energy supply system (besides ensuring thrift and energy efficiency in all spheres of human activity) is involving school going children in this pursuit. With their open and, to a large extent, unpolluted minds it is possible to befit immensely by making them the primary agents of short term and particularly of long term changes in the energy sector. There is sufficient reason to believe that equipped with right knowledge and understanding, these future decision makers of the planet can not only make profound contributions towards renewable energy based supply mix but also provide much needed impetus for moving towards a sustainable society.

2. Relevance of Renewable Energy Education at School Level:

In many countries of the world, depending on the age and level of their schooling, the children may already have some awareness about different sources of energy, need to conserve energy, relevance of harnessing renewable sources of energy, and other relevant aspects. Moreover, in the science and/or environmental studies curricula of school children various different aspects of energy (including renewable energy) can be introduced. It is necessary that schools in all countries of the world make such an attempt with the requirement being more critical for developing countries in view of their rapidly increasing energy demand and urgent need to work towards ensuring sustainable ecosystems. If the students are made cognizant of the issues and also made interested in the subject at young age with the challenges appropriately defined to them (without introducing any biases) it is expected that appropriate and implementable solutions would subsequently emerge. For example, elementary school education has been found to be the most crucial stage for acquiring knowledge as well as for shaping attitudes and behaviours of school going children. It is therefore possible to introduce basic concepts as well as advanced features of renewable energy technologies with the help of proper educational tools. The school children can gradually be provided information about the potential, limitations and

challenges in harnessing renewable sources of energy besides exposing them to various existing and potential modalities of renewable energy utilization.

There have been many studies that have attempted to examine the attitudes of school going children towards science in general and renewable energy in particular [7-26]. Similar attempts have also been made to assess the awareness of pre-science teachers about renewable energy [27-30]. Studies to assess the effect of home, school and mass media on the knowledge, attitude and perceptions of students have also been reported [31-32]. Results of a study that assesses the awareness about renewable energy in vocational and technical education have been reported [33]. A strong need has been felt to establish interaction between the educational and energy related policies of a country so that all latest developments in the field of renewable energy are internalized in decision making at policy level [34-35].

Renewable energy education can be imparted at different levels and through different modalities [4]. In each case, one of the important learning outcomes must be to develop requisite competency (knowledge, skills etc.) needed to undertake various activities to be undertaken on successful completion of education as stakeholders in large scale development and deployment of renewable energy technologies. Of course, the scope and coverage of a particular programme aiming at renewable energy education would vary at different levels and also with the approach and modality adopted for imparting the same.

Renewable energy education programmes at university level were initiated in many countries of the world after the oil crisis in 1973 with most of the activities being at postgraduate level. Gradually, some programmes were also offered at undergraduate level though their numbers are still relatively much smaller. In some developed countries (such as Australia, Canada and USA) attempts were also made to consciously introduce renewable energy related concepts in the school level curricula. Gradually, some other countries have also started introducing topics pertaining to renewable energy resources and technologies in their school curricula [4]. However, still, particularly in most of the developing countries, the renewable energy education at school level merits special attention along with concerted efforts to ensure an integrated and holistic renewable energy education programme in the country.

At school level there is an imminent need to strongly correlate the curricula for renewable energy education with the science education curricula. To the extent possible, the goals and objectives should be aligned with the relevant national and international standards that pertain to science education. There is very high feasibility of designing cross-curricular lessons that also internalize concepts of mathematics, reading, language, arts etc.

For imparting renewable energy education, particularly at the school level, activity based learning supplemented with suitable models, demonstration and planned experiments etc. is an essential ingredient. Such activities are likely to provide first-hand experience with renewable energy devices, systems and facilitate reinforcement of renewable energy related concepts. Through these activities it is possible to offer a variety of inputs at varying levels of expertise in different subject areas. Renewable energy activities, projects, experiments etc. can help broaden the knowledge and understanding about renewable energy and also about the scientific methods involved. Immediately after the first oil crisis of 1973, efforts were made in several countries of

the world towards developing and disseminating models and experiments to provide the much needed exposure to and appreciation of renewable energy sources and technologies to the school going children. However, in many countries of the world, that include most of the developing countries, very little institutional effort has been made in this regard. In view of large potential and urgent need for the developing countries to increase the share of renewable energy in their supply mix, it is critically important that functional institutional arrangements are established and strengthened in all developing countries to impart renewable energy education at all levels with particular emphasis to its school education component. It is with this background that this chapter has been prepared to provide a brief overview of various different aspects of activities on renewable energy that can be offered to school going children. It is worth mentioning that the word 'activities' as used in this chapter also includes experiments, projects and any other suitable mechanism of engaging with the school going children with an objective of initiating them in the field of renewable energy. It is also envisaged to develop one or more project(s) that focus on facilitating the availability of models, experiments and other suitable teaching-learning resource materials for imparting renewable energy education at school level in developing countries.
Activities have been found to very effective even at pre-school level in facilitating suitable environment to kids towards developing their cognitive skills. The same have considerable impact on their problem solving ability and also on their ability to observe, explore and research.

3. Relevance of Activities/Experiments/Projects in Imparting Renewable Energy Education to School Going Children

The primary aim of these activities is to have the children explore and understand renewable energy through highly engaging activities. In order to learn it is important to observe (the same things often) and compare them. Activities and projects are expected to broaden knowledge and understanding of the school going children in the field of renewable energy and also contribute towards inculcating and reinforcing scientific methods of enquiry. Most often, the activities and projects apply the basic principles of biology, chemistry, physics and mathematics to observe, understand and analyze the same. Wherever applicable and feasible, it may also necessitate use of sensors, tools and instruments so as to obtain relevant information from the surroundings.

The relevance and effectiveness of hands-on, project based learning methods for teaching renewable energy courses to engineering students is well established [4,36]. The students gain practical skills for fabrication, testing, system design etc. The main goal of engaging students in activities is to excite the students about renewable energy and to inspire them to contribute towards increased dissemination of renewable energy technologies. Activities have been found to be very effective in connecting lecture sessions with the requirements in the field.

There has been increasing awareness towards making schools energy conscious and help them in adopting energy efficiency measures and also towards harnessing renewable sources of energy [37-41] As early as in 1982, efforts towards developing simplified solar energy gadgets that can be used schools were made at the Centre for Energy Studies of the Indian Institute of Technology Delhi in India [42-43]. As expected, the primary objective of the initiative was to sensitize school going children to the relevance of harnessing solar energy as an environment friendly resource. A variety of solar energy based inexpensive gadgets using locally available materials

were developed as teaching aids for engaging the school going children in activities (some of these gadgets are shown in Appendix-I). Another similar example is that of Solar Energy Research Center of the Dalarna University Falun (Sweden) that contributed immensely towards developing gadgets for offering activities to school going children and also providing exposure to public [44-50]. Some of these activities demonstrated at the Science Centre 'Teknoland' located in Falun, Sweden are shown in Appendix-II.

Activities often provide opportunity for interactive and thought provoking sessions with the students that help in focusing the attention of the students on a specific issue and make them interested to explore further on the topic [51] For example, in case of primary school students, the activities may help them learn making observations, measure, record observations, compare and contrast the same, analyze and present results and draw inferences from the results obtained. One of the expected benefits of offering activities/experiments/projects to school going children is likely enhancement in the meta-cognition of the students. It is worth mentioning that the meta-cognition essentially represents the ability of an individual to reflect, understand and control their thinking and acting [7]. Engagement in suitable activities have been found to significantly improve the attitude and increase knowledge of students and the same is attributed to the sensory stimulation generated by the teaching aids used and associated affective responses [13]. As per constructivist theory a curriculum should contain activities and other relevant components so as to enable students to learn through exploring [34]. According to this theory, individuals do not accept the knowledge as the same is presented to them. Instead they construct and use the knowledge on a distinctive basis. The school students can be made to participate in a variety of activities that provide directly relevant information towards harnessing renewable sources of energy [52]. Use of integrated e-learning approach that is based on the utilization of experiments as well as educational e-materials in enabling students to understand all relevant facets of science subjects have also been suggested [53].

In view of its relevance and great potential, presently there has been very little attempt towards sharing the information regarding development and implementation of renewable energy related activities/ experiments/projects for school going children. While some of the authors have published research papers on various relevant aspects of renewable energy based activities [54-87], substantial amount of material is available in terms of reports or often uploaded on web [88-99]. In the remaining sections of this chapter, an attempt to present information as compiled from the literature on various aspects of offering activities/experiments/projects to the school going children have been made. These include objectives (expected learning outcomes), classification, desirable characteristics, different steps involved, teaching-learning resource materials, sample list of activities and a review of different relevant considerations in offering activities on renewable energy to school going children. A significant share of the material included in the chapter is compiled using the information made available in a large number of web based sources and at times it has not been possible to cite a specific standard reference for the source of information. The authors gratefully acknowledge the information received from all such web based sources.

4. Expected Learning Outcomes of Activities and their Desirable Characteristics

On the basis of a preliminary review of different education standards (primarily those on science education) various broad learning outcomes that are expected to be achieved on successful completion of an activity/experiment/project on renewable energy may include:

(a) Use appropriate tools and techniques to collect and analyze data
(b) Identify a problem
(c) Develop descriptions, explanations, predictions and models using evidence
(d) Think logically and critically to develop and establish suitable relationship(s) between evidence and explanation(s)
(e) Propose designs and choose between alternative options/solutions for harnessing renewable sources of energy
(f) Evaluate each of the options/solutions based on both conventional as well as renewable sources of energy and analyze their consequences
(g) Implement a proposed solution
(h) Understand various possible modes of transfer, conversion and conservation of energy
(i) Develop an understanding of the effects of various energy resource-technology combinations on the environment and decision making regarding the choice of the same with due consideration of trade-offs between positive and adverse impacts of the technology on the environment
(j) Develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving
(k) Appreciate the relevance of experimentation, research and development, invention and innovation, trouble shooting etc. in providing solutions to the problems and challenges faced by mankind in the field of energy
(l) Understand the need for multidisciplinary approaches for resolving technological challenges in the energy sector
(m) Understand, select and use appropriate energy resource –technology combinations

It is worth mentioning that a single activity may not be able to contribute towards all the learning outcomes listed above. However, each of the activities offered to the school going children should be designed so as to maximize their impact in terms of one or more of the learning outcomes mentioned above.

An activity is expected to directly and indirectly contribute towards development and inculcation of the following abilities in the school going children:

(i) Ability to sequentially follow various steps of the scientific process, i.e. hypothesizing, observing and/or recording data, drawing inferences and comparing the same with initial hypothesis
(ii) Ability to ask questions relevant to the topic thus demonstrating higher level of thinking
(iii) Ability to demonstrate thorough knowledge and understanding of concepts through oral and written communication
(iv) Ability to present the objective(s), approach followed, observations made as well as conclusions drawn in the form of an activity completion report (that invariably also includes properly labeled schematic diagrams, limitations of the study etc.)

The activities on renewable energy that are offered to the school going children should preferably have a variety of characteristics to ensure that the same are able to contribute towards

the primary objective(s) and also towards inculcating the above-mentioned abilities. Some of these characteristics are listed below:

(a) Ability to attract and maintain interest, curiosity and motivation of the school going children
(b) Inputs within the grasp of the children
(c) Integration and synergy with inputs in other subjects
(d) Linkages and relevance to contemporary media and social discussions
(e) Special care in ensuring that only non-toxic materials are used in activities aiming at renewable energy education of school going children
(f) Explicitly specify, to the extent possible, the expected learning outcome, details of the observations to be made, precautions to be made and likely sources of error during the conduct of each activity
(g) Ensure to point out and explain the limitations of renewable energy based energy supply options (for example low flux density, variable and intermittent resource availability of solar and wind, seasonal and annual variations in resource availability of solar, wind, biomass and hydro etc.
(h) Ability to identify issues and challenges in harnessing renewable (solar, wind, biomass etc.) energy for different end uses -cooking, lighting, water pumping, space heating, space cooling, transport etc.
(i) Gradual increase/advancement in the level of inputs being introduced in successive activities
(j) Use of locally available materials in fabrication/manufacture of equipment, resource materials etc.
(k) Ensuring synergy between demonstration experiments, hand-on experiments and other activities undertaken by the children
(l) A well defined self study component with each activity (prior to or after the activity)
(m) A component exploring the possibility of adopting renewable energy technologies at household level/ at school/within the local society
(n) Direct connect with day-to-day happenings in life and sensitization of the school going children on a variety of relevant issues faced by the society (depletion of fossil fuel reserves, climate change, energy security etc.)
(o) Understanding linkages between local actions and their global implications
(p) Instructions in local language, ensuring availability of teaching – learning resources
(q) Inculcating leadership quality amongst children-representing a group while performing activities and periodic change of the group leader
(r) Wherever feasible, involving parents and other family members in the activities to be undertaken by the students

5. Classification of Activities

The activities (also including projects and experiments etc.) on renewable energy that can be offered to school going children can be characterized and classified in terms of a variety of attributes. These include:

(a) Renewable energy topics covered- single resource/multiple resource

(b) Level /standard of schooling- pre-school, primary school, secondary school, senior secondary school
(c) Single discipline versus multi-disciplinary activities – some activities may require group discussion to reach conclusion
(d) Hardware intensive/discussion based/ web-search based- Activities that require use of gadgets or equipment for demonstration or activities that involve hands-on activities to be undertaken by the students or activities that try to build on the existing awareness and exposure of students and around the energy resources surrounding them. The last category of activities essentially depend upon (and encourage also) discussion in the class room
(e) Choice of materials used- whether use of locally available materials with some compromise/constraint is acceptable?
(f) Indoor and/or Outdoor
(g) Simulation and/or demonstration model or field size equipment or system
(h) Demonstration(teacher) /Hands-on (by student)
(i) Observation based/Analysis based – some activities may try to build on existing awareness and observations of the students about their surroundings and such activities would often necessitate a discussion in the classroom
(j) Short duration/long duration (multiple attempts such as those on biogas, storage etc.) – time required for undertaking the activity (or number of laboratory hours required for successful completion of the activity)
(k) Quantitative results versus Qualitative appreciation of the concept/principle/impact etc. Sometimes, it may be easy to qualitatively demonstrate but its quantitative verification could be difficult. For example, while studying the effect of colour on absorption of solar radiation by putting identical ice cubes on metallic sheets painted with different colours the time of melting of ice cubes on black and blue colour sheets may turn out to be almost equal
(l) Role of potential uncertainties and assumptions during the conduct of activity
(m) Pre-requisites in terms and knowledge and skills for undertaking the activity and also for being able to infer and appreciate the conclusions of the same. Thus the preparedness of the students to understand, undertake and interpret the results of the activity has an important role in the success of an activity in achieving the desired learning outcome(s).
(n) Single (Individual) student/group of students/entire class/ only teacher for conducting the activity-need for group discussion
(o) Mandatory/Voluntary nature of activity (in terms of performance assessment of the student)
(p) Objective- to impart knowledge/understanding/capability to analyze and/or synthesize
(q) Pedagogy- storey, questions etc.
(r) Commercially available kit/self organized or assembled
(s) Suitability for any specific geographical area(s)/regions – cold regions, warm regions, developed countries, developing countries
(t) Extent of synergy with efforts towards imparting education relating to conventional energy and/or energy efficiency and energy conservation and/ or environmental sustainability
(u) Linkage(s) with broader social issues to ensure proper engagement of students

(v) Additional action projects/activities as an offshoot of the activity being undertaken-ability to spark interest in the student
(w) Participation of students in recording observations and their analysis-each individual, group, teacher
(x) Extent of preparedness required prior to the activity experiment- briefing by the teacher just before the experiment, students given relevant material in advance to come prepared for the experiment
(y) Monetary cost of undertaking the activity

As indicated earlier, the type and scope of activities offered to the school going children would also depend upon several considerations that depend on their own attributes. These attributes include:

(a) Age of the children
(b) Level/class in the school
(c) Attainment in other educational activities
(d) Available time slot and time duration for participation in the activity – for example, under Socially Useful Productive Work
(e) Ability to do mathematical calculations

6. Steps Involved in Offering Renewable Energy Activities

An activity on renewable energy for engaging school going children can be broadly divided into following components (presented from the perspective of the child performing the activity):

(a) Selection: Identify the specific area of interest, gather information and make a choice of the activity within the area of interest
(b) Information Collection: Undertake literature review and collect relevant information from all available resources on the specific area chosen for the activity
(c) Discussion: Discussion on the selected activity within the group of students undertaking the activity and also with the teacher(s) and accordingly collect additional information
(d) Defining Scope: Plan the activity envisaged by explicitly yet concisely defining the objective(s) and the scope of the activity as well as the important questions that are likely to be answered through the activity on its successful completion
(e) Hypothesis Formulation and Planning the Activity: Formulate a hypothesis pertaining to the specific problem chosen and plan for undertaking the activity
(f) Arranging Materials and Equipment: Arrange the required materials as well as the equipment in consultation with the teacher(s)
(g) Conduct of Activity: Start the activity as per the investigations planned with the progress being shared with the teacher at regular periodic intervals (in a large number of activities, a close supervision by the teacher(s) would anyway be necessary). Maintain a notebook with full details of actions, observations, changes made and any other relevant remarks at frequent periodic intervals as suggested by the teacher(s)
(h) Analysis: Analyze the observations made to obtain results, interpret the results, draw inferences and discuss the same with the teacher(s). This could involve mathematical calculations as well as making graphs, charts, tables etc.
(i) Report Preparation: Make the final report (and if applicable, prepare a poster for display)
(j) Presentation: Make an oral presentation on the activity for sharing the results.

7. Approaches and Avenues for Offering Activities

There are several different approaches that may be used to engage school going children in activities/experiments/projects in the field of renewable energy. These include:

(a) Class rooms and/or laboratory contact hours- offering opportunities to participate in activities within the regularly scheduled class room and/or laboratory contact hours

(b) Demonstration models and/or working systems in schools- Activities could also be designed around functional renewable energy systems installed within or around the school premises. The children may be involved in making an recording observations and using the same do calculations as required for the systems.

(c) Field visits- The children visit functional renewable energy systems and the same provide an excellent opportunity to the school going children for pre-visit discussions, making observations during the visit, comparing different options etc. At the end of the visit, each of the participating children may be asked to prepare a report on the visit that also presents their learning and impressions of the systems visited. Unavailability of renewable energy installations in the nearby areas could be a constraint in benefitting from this mode of engaging in activities.

(d) Science centres – These can also be effectively used for providing exposure to school going children regarding different types of renewable energy technologies as well as various scientific concepts involved in harnessing renewable sources of energy. However, as in the case of field visits, not all schools would have the privilege of having a science centre (having exhibits that deal with renewable energy) within reach for the visit of the students.

(e) Renewable energy exhibitions/fairs and competitions - An activity such as a renewable energy fair is expected to develop and inculcate positive practices and attitudes in school going children (Tsagliotis Nektarios)??? [ ]. Such fairs also provide an opportunity to the children to create their own models (functional or otherwise) and get actively involved through hands-on activities besides sensitizing the visitors to the fair about potential of harnessing renewable energy for a variety of meaningful and useful purposes. For a student centric renewable energy fair, the children are motivated to select a particular topic of their interest, undertake background study, clarify their initial doubts and queries, and then facilitated towards a structured scientific investigation for acquiring in-depth knowledge and understanding. In the next phase, the school going children are made to get involved in group activities to develop models and projects with their teachers providing help in the investigative component of the same. Teachers also provide help in making available the materials and equipment required for the project/model. At the end, an open exhibition of the projects and models etc. developed by the children is organized for the public. The children are encouraged to explain their projects and models to the public and also to answer any questions asked. The renewable energy fair may then culminate with the award of certificates to all children participating in the fair and medals and awards to the selected projects/models.

Renewable energy being an interdisciplinary subject, it may be desirable to organize the fairs on cross-curricular themes that carefully link a variety of school level subjects such as science, mathematics, social studies etc. However, a renewable energy fair can also be organized around a specific theme (for example, photovoltaics and its applications, small hydropower, industrial applications of biomass feed-stocks etc.). To the extent possible, a renewable energy fair should ensure a judicious balance between formal and informal content in the teaching learning process. This is necessary to ensure that too much emphasis is not given on the exhibition component of the fair at the cost of conceptual clarity and deeper understanding on the subject matter. Similarly, an over emphasis on formal learning component may compromise with the investigative and inventive objectives of the renewable energy fairs.

8. Assessment and Evaluation on the Activity Undertaken

One of the simplest approaches suggested for assessment of students (school going children) after individual or group activities (or at the end of the unit involving the activity) is to assign specific questions(s) to each student (or alternatively give students a choice of several questions to choose from). As an example, a set of sample assessment questions on a few broad topics is listed in Table 1.

Table 1. Examples of assessment questions

S. No.	Broad Topic	Assessment Question/Assignment
1	Non-Renewable Sources of Energy	(a) Name at least two non-renewable sources of energy that can be traced back to the Sun. Explain the role of solar energy (the Sun) in their formation.
		(b) Discuss the time trend of fossil fuel consumption in the country and also in the world.
		(c) Describe and discuss the adverse environmental impacts associated with harnessing of fossil fuels.
2	Renewable Sources of Energy	Name at least three renewable sources of energy and also explain how the same are indirect forms of solar energy
3	Role of Solar Energy in Eco-system	Explain the role of solar energy in food web, in the water cycle and also in the creation of wind
		Explain the role of photosynthesis in human life.
4	Solar Collectors	Give real life examples for illustrating the effect of colour of a surface on the fraction of incident solar radiation absorbed by it.
5	Solar Thermal Devices	Draw a schematic diagram of a box type solar cooker or a solar oven for construction and demonstration of solar cooking. Explain the choices made with respect materials of construction as well as the design features of the cooker.

In another approach suggested for assessment and evaluation of senior school students on the activities assigned to them, a five point scale as presented in Table 2 is used

Table2. Five point scale for assessment for activities/experiments/projects.

Point	Observation During Assessment	Remark
1	The student did not gain knowledge or acquire skill at all.	Knowledge and/or Skill absent
2	The student has gained some knowledge and acquired skill but errors and omissions are observed.	Knowledge and/or Skill with errors and omissions
3	The knowledge and skill almost mastered but some deficiencies observed	Almost there in Knowledge and/or Skill acquisition
4	Acquisition of both knowledge and/or skills mastered to expected levels	Expectation on Knowledge and/or Skill acquisition met
5	Unusually high quality of work demonstrating skills and/or knowledge acquisition way beyond expectations from a school student	Beyond Expectations

9. Renewable Energy Education Opportunities for School Going Children under Service Learning Projects

Academic as well as research and development institutions engaged in the field of renewable energy can offer opportunities to school students (9-12 grades) in action oriented, project based service learning [100]. Educational resources available with such institutions can be used to provide exposure and training to school students besides making them aware of the social and environmental concerns and challenges. Also the school students can be motivated to acquire skills that are suitable for green careers. In the United States of America, under the service learning scheme, such institutions work in collaboration with schools for implementing projects that also involve development of appropriate curricula, training of school teachers and direct technical support for field level activities.

Service learning essentially provides an opportunity to the school students for experiential education as they work with others to apply the knowledge and skills acquired to community relevant issues and problems. During this process, through their actions and by reflecting on their experience of working on real projects relevant for the community, invaluable learning occurs. Through this mode the community members receive valued service and institutional support while the students apply class room knowledge in practical settings and can also enhance their interpersonal and organizational skills and self confidence. For example, the students can (i) undertake energy, water and waste audit in their school and identify opportunities for resource conservation, (ii) conduct sustainability audit of local business and commercial units, (iii) design a business enterprise that imbibes sustainable development (iv) assess feasibility of renewable energy utilization in school and other locations within the community, (v) building improved biomass cook-stoves or solar cookers for residential use etc.

Some of the desirable characteristics of service learning projects based approach for imparting renewable energy education to school going children are listed below:

(a) Students, teachers/instructors and partners from community level organizations play critical roles in developing and executing effective and efficient service learning activities.
(b) Service learning projects should be directly related to the course content as applicable to the student and should not compromise academic rigor with the learning credit assigned for learning and not for service
(c) Learning goals of the service learning projects should be clearly identified and specified. It may be desirable to restrict service activities and contexts so as to ensure that the same have potential to meet envisaged academic objectives as stipulated for the course.
(d) Service learning projects should provide meaningful service addressing perceived need(s) of the community.
(e) Projects under service learning should provide the students ample opportunities for critical reflection upon their service experience.
(f) Service learning equally emphasizes both learning and the service and attempts to make them mutually reinforcing by ensuring an academic context while meeting genuine community need(s) through meaningful tasks undertaken by the students.
(g) Service learning pedagogy should be flexible with the possibility of making use of different variety of service opportunities, classroom settings and capable of supporting various learning outcomes.

10. Current Status of Teaching-Learning Resource Materials for Renewable Energy Education at School Level

Even a simple Google search on "school experiments on renewable energy", or "renewable energy activities for kids" indicates that a reasonably large number of companies, NGOs, government and private institutions as well as individuals have interest in this area and have developed equipment, models, experiments, games, quizzes and other resources for this purpose. The countries that took lead in this direction with resource materials (prepared in English language) include United Sates of America, Canada, Australia and United Kingdom. Though it is difficult to present a definitive time trend of the efforts being made to develop and use models, experiments, activities etc. for introducing renewable energy to school children, it is worth mentioning that some of the resource materials were prepared immediately after the first oil crisis in early nineteen seventies [5]. While information about some of these materials is free to download (and use), a substantial fraction of the same is priced. Often the materials used in making the teaching-learning resources vary with the location. As expected, the existing information requires consolidation and a careful review for its use in schools of developing countries. For example, to the extent possible, an attempt needs to be made to reduce the cost of the suggested learning resources (of course without compromising with the intended purpose) so that maximum number of schools can benefit from their use.
The details of a renewable energy based activity/experiment for offering to school going children should include:

(a) Objective (purpose) of the activity (what is expected from the activity-learning outcomes)
(b) Materials and equipment needed for the activity
(c) Information about procurement of the materials and equipment required for the activity

(d) Details regarding assembling and conduct of the activity
(e) Observation(s) to be made while conducting the activity
(f) Calculations to be made using the observations made during the activity
(g) Inferences likely to be drawn from the activity and comparisons to be made of the inferences with the initial expectations and predictions
(h) Modalities of assessment of the students on activities undertaken
(i) Suggestions for reinforcement and/or potential extension of the activity

Preferably, proper lesson plans should be prepared to offer an activity. Some such lesson plans are available on the web and can be made use of. Attempts to develop lesson plans for school teachers desirous of introducing renewable energy through activities/experiments/projects have also been made. The lesson plans can be developed for both single day and multiple day activities. Each lesson plan may include (a) an introductory description, (b) an activity to understand the value of renewable energy resources, (c) research on specific sources and their conversion.

The teaching-learning resource materials that can be used for offering activities/experiments/projects on renewable energy to school going children should preferably be integrated into their reading curriculum. While some of the resources should be studied prior to undertaking the activity, the students should be encouraged to study the relevant material(s) after conducting the activity. The school going children may also be asked to read the learning resource(s) as a formal assignment and then asked to write a comprehensive report on the same. The resource material should preferably be prepared for the specific grade or level of the student and should include guides for the student as well as for the teacher. Brief details on two of the important resources for offering renewable energy based activities to school going children, i.e. (i) activity booklets and (ii) renewable energy installations in schools are presented in the following paragraphs:

Activity Booklets

It is very important to develop user friendly activity booklets on all different types of renewable energy sources (such as Solar, Wind, Hydro, Biomass, Tides, Waves etc.) and technologies for harnessing them. Such activity booklets should be accessible, easy to use and fun besides providing much needed inputs to the students for appreciating various relevant aspects of renewable energy utilization. In a broader sense, these activities should also instill into the minds of the students greater confidence in investigating, questioning, experimenting, and analyzing scientific issues and challenges. As a broad guideline, each activity should usually answer at least one original question and also help raise one or more questions for further investigation and study. At the end of the activity, the students need to write about and/or present the process, observations, results and conclusions in terms of a report and/or a poster display. The activity booklet should provide suitable guidelines and preferably a sample report for the benefit of students.
Activity booklets can also be developed to facilitate a variety of practice-cum-fun sessions for the students. The items that may be included pertain to

- Fill in the blanks in one or more paragraphs by using an ANSWER BANK that gives several answers each to be used only once.

- Match a given description in a statement (or paragraph) with the correct word in the ANSWER BANK to make a proper linkage
- Unscramble the missing words while learning about important concepts
- Mathematical challenges based on some basic information provided
- Crossword puzzle
- "FORTUNE TELLER" game to be played with friends in the class that relates the choices made by the society of its energy sources on the climate and other important aspects

Another interesting approach used towards introducing renewable energy sources and technologies to school going children is that of using colouring, comic, and cartoon books. The children acquire important factual information on various relevant aspects of renewable energy utilization while colouring the diagrams/figures given in a colouring book and reading the brief notes given with the figures. The figures that are coloured may depict renewable energy resources, their natural manifestations, as well as the technologies used for harnessing them. During the process of colouring several new shapes and designs emerge that help reinforce important characteristics of the renewable energy resources and technologies.

Renewable Energy Installations in Schools

Studies have indicated that there is a strong positive correlation between educational facilities at the school and student achievement. For example, improvements towards making the school campus environment friendly have reportedly affected academic achievements in a positive manner. While cost effective renewable energy installations in schools can be used to provide hands-on activities to the students, they also have an opportunity to observe and experience the operation of these functional systems on field. The students can be involved in determine the energy delivered by the renewable energy systems installed in the school campus, make comparisons with corresponding data from other schools having similar systems and also use the same for estimating amounts of greenhouse gas emissions mitigated. On-campus renewable energy installations can also provide with a powerful educational tool to facilitate teaching by example.

11. **Spectrum of Broad Potential Concepts and Specific Topics for Activities**

A large variety of topics may be made the focus of activities/experiments/projects on renewable energy offered to school going children. Given below is an exemplifying list of broad concepts around which the activities could be developed. Additional exemplifying details are presented in Appendix-III for a few components while initiating activities on renewable energy for school going children.

(a) Energy and its different forms and their inter-conversion
(b) Energy conversion, transfer and conservation, modes of heat transfer, reducing thermal losses
(c) Different approaches for electricity generation, components of electrical power systems, processes involved in energy delivery from different fossil fuels- energy supply chain – exploration, extraction, conversion, transport, storage, distribution and utilization of fossil

fuels, Uneven/inequitable geographical distribution of fossil fuels and its implications for fuel importing countries

(d) Determinants of energy demand of a household, country, relative share of different sources of energy in the supply mix of a country and its time variation, Time trend of energy demand, fossil fuel availability and concentration of carbon dioxide and other greenhouse gases in earth's atmosphere
(e) Human needs/desires and need for producing goods and services-need to do work-energy requirement
(f) Energy and (i) quality of human life, (ii) economic growth
(g) Impact of population growth on energy demand, consumption of fossil fuels and other mineral resources
(h) Nutrient recycling, carbon cycle, nitrogen cycle, water cycle
(i) Natural resources and their relevance in our daily life, Interdependence of humans on other biotic and abiotic things, biodiversity, food chain
(j) Concept of efficiency of fuel utilization, Efficiency of fuel utilization for different energy resource-technology combinations, energy efficiency measures, thrift, energy conservation, relevance of fuel and factor substitutions and their practical applicability
(k) To explain the need and relevance of energy end use matching – quality of energy demanded and quality of energy used (issues with heating water for meeting human bathing requirement with electricity instead of using solar water heating systems)
(l) Barriers to the acceptance of renewable energy technologies at decentralized as well as centralized level
(m) Greenhouse effect, global warming, climate change, life cycle emissions, cradle to grave analysis, carbon footprint of humans
(n) Difference(s) between renewable and non-renewable sources of energy
(o) Indoor, outdoor pollution caused by activities in energy sector (extraction, conversion, transport, storage, utilization of fossil fuels) – land, air, water pollution; Effects of pollution on humans and on ecosystems
(p) Different types of renewable sources of energy, their characteristics and utilization potential, Variation in the availability of renewable sources of energy – hourly, daily, seasonal, annual variation
(q) Technologies for harnessing renewable sources of energy and processes involved
(r) Concepts of quality degradation upon utilization of energy, embodied energy and embodied emissions, energy intensity of goods produced and services provided, monetary cost versus energy cost, material usage in energy sector, implications of material usage for energy requirement and consequently for environmental emissions
(s) Hybrid and integrated energy systems
(t) Need for energy storage – storage related characteristics of different sources of energy

The activities, experiments and projects can also be designed to reinforce some of the well known facts pertaining to renewable energy. Examples of some explicit objectives of the activities/pre-activity discussion in the classroom are listed below:

(a) All living beings and natural processes require energy
(b) Sun is the primary source of energy- most of the energy on earth originates from the Sun
(c) Solar energy drives the water cycle

(d) The sun produces enormous amounts of radiant energy
(e) Solar radiation travels long distance through space
(f) Solar radiation produces heat upon absorption
(g) Warm air expands and rises as it is heated
(h) Wind is caused by unequal heating of earth by solar energy (and is hence an indirect form of solar energy)
(i) Amount of solar radiation available at a location on earth depends on its latitude
(j) Life on earth is made possible by greenhouse effect
(k) Solar radiation can pass through some materials and is reflected by some
(l) Absorption of solar radiation by a surface depends on its colour
(m) Humans and other living beings use Sun's energy to see
(n) Plants converts solar energy into chemical energy that provides food for growth and life
(o) Fossil fuels and biomass that are used to produce heat and light contain chemical energy from plants and animals.
(p) Solar energy has very low flux density (small amount of energy per unit area per unit time) as compared to fossil fuels
(q) Solar collectors can be used to collect and absorb solar energy and convert the same into heat
(r) Solar photovoltaic (PV) cells convert solar energy directly into electricity
(s) Environmental impacts of energy utilization differ depending on the energy resource and the conversion technology utilized
(t) Human society is strongly dependent on non-renewable sources of energy
(u) Different energy sources have different costs
(v) Conversion of energy from one form to another is associated with some loss.

Finally, a sample list of specific activities/experiments/projects that can be offered to school going children is presented below:

(a) Preparing a survival plan (individual/family/city level) for the case of exhaustion of fossil fuels
(b) Assign a renewable energy topic to a group of students or to an individual student, assess their existing knowledge on the topic, motivate them to undertake more study(research) on the topic and ask them to prepare a report on the incremental knowledge acquired
(c) To create an energy collage that classifies different kinds of energy
(d) Using a step-by-step do-it-yourself manual construct a solar oven or a box type solar cooker or a paraboloid concentrator solar cooker and observe the transformation of solar radiation into thermal energy. Also to use the solar cooker for preparing food
(e) To measure the DC voltage output of a solar cell
(f) To study the effect of tilt and/or orientation on the electricity output of a solar photovoltaic panel
(g) To study the effect of amount and wavelength of light on the output a solar cell
(h) To study the effect of temperature on the performance of a solar cell/module
(i) To study the effect of series and parallel combinations of solar cells on the output (voltage and current)
(j) To compare the electricity outputs of two identical PV modules in tracking and non-tracking modes of operation

(k) To study the effect of shading on the output of (a) solar cell, (b) solar cells connected in series, (c) solar cells connected in parallel
(l) To study the effect of distance of PV cell from the source of radiation on its output
(m) Using solar cells to power motors, pumps, luminaires (electric lamps-LED lamp, CFL etc.)
(n) Building a solar powered vehicle and racing the same
(o) Conversion of solar energy into mechanical energy
(p) To construct a solar water heating system with a solar collector and a storage tank and measure the temperature of water in the tank at different times of the day
(q) To construct a solar air heater, tests its performance and make arrangements to install the same on the south facing window
(r) Build a solar purifier
(s) Demonstration of flow of water in a two tank solar water heating system
(t) Building a water turbine
(u) Making a Sundial
(v) To demonstrate greenhouse effect
(w) Building a small scale biogas digester and producing biogas from organic wastes
(x) Construction of a Savonius wind turbine
(y) Construction of blades of a wind turbine
(z) Making an anemometer and measuring speed of wind
(aa) Comparison of different types of thermal storage options
(bb) To compare the efficiency of ethanol production from various sources/feed-stocks-table sugar, grain crops, fruits, cellulose, corn-cobs, corn silage etc.
(cc) Making biodiesel from waste oil
(dd) Using solar photovoltaic modules to power headlights of a car
(ee) Selecting feed-stocks best suited for producing methane gas through anaerobic digestion
(ff) To compare the calorific (heating) value of different biomass feed-stocks
(gg) To study the factors affecting biomass growth
(hh) Comparison of techniques that can be used to measure and compare wind direction and speed
(ii) To study the effect of rotor shape and size on the amount of electricity produced by a wind turbine
(jj) To study the effect of different modalities of spacing wind turbines on a given piece of land on the total output of a wind farm
(kk) Design and construction of a solar concentrator (parabolic trough).Also design its tracking system and study its performance
(ll) To study the effect of insulation type and thickness on the performance of (a) box type solar cooker (b) flat plate solar collector
(mm) To estimate greenhouse gas emissions from energy use in a household
(nn) To study the effect of vacuum on heat losses from a solar collector and also on temperatures achieved
(oo) Making a simple air-conditioning unit by using solar cells and cooler elements
(pp) Reducing smoke produced by a stove/ boiler/furnace etc.

12. Examples of Few Projects for Promoting Renewable Energy Activities amongst School Going Children

(a) **KidWind Project:** It involves a team of teachers, students, engineers etc. that is exploring the science behind wind energy in classrooms around the USA with the cognizance of the fact that the inputs provided to school going children have far reaching implications and the same could be an important foundation for future initiatives of the children. The primary objective of the project is to introduce the relevance and characteristics of renewable energy sources and technologies through science based hands –on activities that are challenging and engaging. On successful completion of the project, it is expected that the students would have a more robust understanding of the opportunities offered and challenges presented by wind energy technologies for large scale utilization

(b) **Mobile Renewable Energy Education (MREE) Project:** This outreach project aims at providing school students and teachers with an applied mathematics, engineering and science curriculum package based on theory and applications of photovoltaics, windpower, hydrogen fuel cells, energy conversion and conservation, energy safety and awareness, global warming etc. This programme makes use of a variety of renewable energy and energy efficiency based hands-on projects for promoting mathematics and science amongst teachers and students in schools. Under this programme, a team consisting of faculty and students offers a series of educational activities essentially aiming at promoting science and engineering education through workshops on applied renewable energy. An objective of the project is to increase the interest of school going children in careers in science, technology, engineering and mathematics (STEM). The project envisages development of partnerships with schools towards improving scientific and mathematical skills of the school going children besides enhancing their technical literacy by creating an environment for understanding interrelationships among sciences, mathematics and engineering through examples from the field of renewable energy.

Another important feature of the MREE project is the use of a mobile unit (trailer) for taking all the equipment directly to the schools to solve the transportation related issues of the students targeted under the programme/project. A mobile trailer was modified to transport necessary platforms for conducting the workshops. Upon reaching a school in which the workshop is scheduled to be conducted, all the platforms are unloaded in an outdoor environment for offering the hands-on activities and experiments. Under the MREE project, the mobile energy laboratory visited a large number of schools to conduct renewable energy workshops consisting of short lectures and hands-on activities.

(c) **RESOURCE (Renewable Energy Systems Opportunity for Unified Research Collaboration and Education) Programme of University of California, Davis (USA):**

It pairs research students from University of California, Davis working on renewable energy technologies with Sacramanto area 5th and 6th grade teachers to develop new science curriculum. This includes lessons in general energy concept, renewable versus non-renewable sources of energy, climate and environmental impacts of fossil fuel utilization. While the research students provide teachers with information on emerging renewable energy sources and technologies to harness them, the teachers help the

research students in improving their communication, collaboration and teaching skills. The programme is funded by NSF GK-12 programme and is a partnership between University of California –Davis College of Engineering and Mathematics, Engineering, Science Achievement (MESA).

School going children participating in the programme learn about renewable energy through lessons with classroom activities that are innovative as well as fun to do as an individual and/or in a group. The inputs provided also integrate with the standard science curriculum requirement of the children. Such a programme is also expected to spark the interest of school going children in science, technology, engineering and mathematics. Moreover, on a broader level, it is also expected that the programmes such a RESOURCE would enrich the knowledge and understanding of school going children about role of renewable energy technologies in addressing climate change threat and encourage them to pursue careers in the field of renewable energy.

13. Important Considerations in Developing Activities on Renewable Energy

From a detailed review of the published literature and of the information available on the websites of organizations involved in developing activities/experiments/projects on renewable energy for school going children, a variety of important inferences can be drawn. These inference need to be carefully considered and internalized while consolidating existing information and making it available for use in the schools, particularly those in developing countries. Some of these inferences and issues (though obvious and simple) are presented in the following paragraphs:

(a) For each activity it is necessary to explicitly define the level of school going children being aimed at so as to target them accordingly. The experiments/activities should preferably involve multidisciplinary inputs and aspects. Activities/experiments that facilitate observation of important phenomena and also those provide opportunities to analyze cause and effect relationships between the determinants and the observed behaviour are very useful towards providing much needed clarity to the school going children. In several cases it should be possible to provide different sets of analyses and corresponding interpretations for different levels of students for the same experiment/activity based on different levels inputs and preparedness of the student.

(b) It is necessary that all the inputs provided to the school going children are scientifically accurate and unambiguous. However, while developing an experiment and /or a model there could often be a need for deciding a trade-off between cost, precision and time required for completion of the envisaged activity. There is often a tradeoff between the scientific accuracy of the activity /experiment and the cost of offering the activity and/or time duration necessary for the activity. For example, sometimes mere qualitative treatment of the topic is presented to convey the message. At times, mere demonstration equipment or set ups or actual systems ready to be implemented in the field are used for this purpose. The language used in preparing any kind of supporting text for an activity must be scientifically precise and based on factual information. Efforts should be made to ensure that the students are able to verify all the claims made and are able to observe any ‘cause’ and ‘effect’ relationship(s) envisaged to be demonstrated through the experiment.

Moreover, any written material prepared for the purpose of sharing with school children should not oversell a renewable energy resource or technology (there is often a tendency to do the same). In fact the student should be made aware of both the strength(s) and limitation(s) (and associated challenges) of each of the renewable energy resource technology combination being discussed. Also the adaptation requirements for the end user of the technology or any further work that needs to be undertaken to overcome the limitation(s) should also be brought into the discussion, at least in a subtle manner.

(c) Each activity would usually require some prior knowledge and skill to perform an experiment and also to be able to appreciate and interpret the results obtained. The pre-requisites in terms of knowledge and skills required to undertake and benefit from each activity/experiment must be carefully understood and analyzed to ensure maximum efficacy of the proposed activity, particularly the ability of students to observe the cause and effect relationship being established in the experiment.

(d) While developing the experiment or an activity different options of materials usage should be considered and tried out. To the extent possible, the equipment, models etc. should be made from locally available materials to ensure continued availability for repair and replacement and often lower cost also.

(e) The activities offered are expected to have better impact if the same are directly relevant to the needs and priorities of the local region and also that of the country. For example, the energy end-use requirements (such as that of heating and cooling) may vary considerably amongst countries or even amongst different regions of a country. Similarly the relevance and suitability of decentralized generation of electricity and other decentralized applications based on renewable energy could strongly depend on the location. While developing experiments/activities on renewable energy for school going children, the extent possible, constant and conscious attempt be made to link the information to broader social issues so as to ensure that the students are adequately engaged and are able to learn in a holistic manner. Thus the objectives, observables and inferences to be drawn from an activity may need modulation accordingly.

(f) In the initial stage the equipment, models and activity should preferably focus on locally relevant aspects of renewable energy utilization so that school going children can easily relate the inputs being provided as well as the activity with their surroundings and routine practice. To the extent possible, renewable energy related experiments dealing with end uses of energy that are commonly observed by school going children should be prioritized.

(g) Each experiment or activity should be designed in a manner so as to be completed within the time period assigned for the same. In case the experiment requires more time or additional visit(s) to observe the effect/result, special scheduling may be needed.

(h) In certain cases there may be a need/possibility of linking and/or consolidating procedures and findings of several experiments/activities conducted simultaneously so as arrive at meaningful conclusion(s). An attempt to design and develop suitable group activities for school going children may also be made. Similarly renewable energy science fairs, exhibitions and competitions can be organized at periodic intervals.

(i) There is often a possibility of a substantial change in the performance of renewable energy equipment on scaling up from laboratory to actual field application size. For example, heat losses from the model of a flat plate solar collector or of a solar passive house could be substantially different from those for field level systems. Thus, adequate

care should also be taken to avoid the risk of over-simplification while performing the activity as against the actual field level operation. For example, a pragmatic approach be adopted in estimating and specifying the potential of renewable energy potential in a specific geographical area (as against highly optimistic or pessimistic values) and also while making efforts to estimate the likely cost of harnessing renewable sources of energy. Depending upon the specific case, such a possibility of over-simplification and the possible reason(s) for the same should be explained to the children engaged in the activity.

(j) To the extent possible, an attempt should be made to inform the student about all assumptions and any simplifying approximations made in the conduct of the experiment/activity and/or in interpreting the results obtained. Any expected deviations at the field level could also be indicated and discussed with the students. Wherever feasible, the students may be asked to analyze and anticipate the deviation in the performance in the field as compared to that observed during the activity/experiment conducted in the classroom/laboratory/demonstration experiment. For example, it would be prudent to discuss the effect of load on the performance of a model wind mill in operation. Similarly relevant issues relating to the durability and or maintenance of renewable energy technologies operational in field, effect of weather, dust, temperature cycling, moisture etc. on the performance and consequent degradation in the performance of the technology with time should to be discussed while performing the activity/experiment.

(k) For each activity, depending on the level of the school going children, a clear distinction is to be made between the extent of observation/ appreciation of the activity and the requirements of recording, presenting and analyzing the data for drawing inferences. As the children grow, their ability to observe and analyze and also their preferences evolve. Therefore, the activities offered should be commensurate with their capabilities and expectations. While it may be useful to introduce to the children engaged in activities the basics of data collection and analysis, it is also important to ensure that the students are able to relate the effects observed during the conduct of the activity with the right cause(s) for the same.

(l) Extreme caution should be exercised in unduly emphasizing on the importance of a particular renewable energy option. Instead, a comprehensive broad outlook that encourages considering all potential options such as thrift, energy efficiency improvement, harnessing of renewable energy sources etc. should be inculcated.

(m) While undertaking activities involving school going children it is important to ensure that the need and relevance of each of the precautions to be observed during the conduct of the activity are properly explained by the teacher prior to conduct of the experiment. Therefore, as a prerequisite, all laboratory manuals, guidelines, handouts etc. must explicitly mention all of the precautions pertaining to each activity. Similarly, during the initial discussion and during the conduct of the activity different potential sources of error should be brought to the notice of the students. Special care also needs to be taken in deciding whether an activity is restricted to demonstration or is offered as a hands-on activity.

(n) There is relatively lesser number of activities for school going children that deal with availability assessment of different renewable sources of energy. However, for the school children to understand specific characteristics of renewable energy sources (as compared

to fossil fuels) it is highly desirable (if not necessary) to develop activities on this aspect as well.

(o) The activities undertaken must synergize with the inputs being provided in the theory component. To the extent possible, the experiments proposed must strive to answer "Why" and "How" etc. of renewable energy utilization besides dwelling on "What" part of the topic concerned.

(p) Another important strategy to involve school going children is to implement renewable energy based solutions in the school itself. For example, the concept of ECO-SCHOOL or NET ZERO SCHOOL or GREEN SCHOOLS or ENERGY SMART SCHOOL etc. can be considered in this regard. Involving students in actual ongoing projects and activities within the school campus would have a profound and long lasting impact on them.

(q) There is an urgent need to involve government educational administration, school administration, teachers of subjects such as science and environmental studies and interested parents of the school children in this endeavor. In the initial stage, it may also be necessary to involve capable entrepreneurs willing to provide quality equipment, models and experimental and/or activity kits for this purpose. Depending upon the level of development of renewable energy technologies, awareness and prioritization by the government, the strategy for establishing institutional framework that promotes and facilitates renewable energy education is likely to vary amongst different developing countries. However, the deliverables and the basic concepts behind the activities offered could be common in all of them.

(r) The school children should be able to enjoy participation in the conduct of activity proposed. It is possible that some students enjoy science but are not keen to get involved in hands-on activities and laboratory experiments. On the other hand, some students may prefer to participate in hands-on activities but do not like the tasks of preparing the reports on the same. Conscious attempts should be made by the teachers to emphasize the importance of being able to undertake the activity and also to be able to write about the same. It is also important to remember that the learning styles of different students may vary from one to another. A mismatch between the preferred learning style of the student and the teaching style of the teacher could lead to student discouragement and consequently reduced inability to satisfy the learning outcomes of the proposed activity.

(s) It would be useful to involve existing science centres and similar other entities in promoting development of dissemination of school level activities in the field of renewable energy.

(t) In most of the schools in developing countries a renewable energy laboratory may not be a part of the school curricula. As a consequence, majority of the school teachers may not have adequate awareness and/or understanding of this new area. Motivating them to effectively contribute towards renewable energy education in schools is critically important. The teachers in schools may require short term training so as to be able to conduct activities.

(u) The activities being offered should facilitate continuous/periodic and consistent observation as well comparison to enable the school going children engaged with the activity infer and learn from the same. Moreover, each activity should preferably specify (at the end of the activity) additional activities/experiments/projects for the benefit of children who are keen to further continue on the specific topic/area of renewable energy.

These additional activities should spark further interest in the right direction and excite them to continue with their interest.

(v) Developing countries would be immensely benefitted by international collaboration in the task of developing experiments and activities in the field of renewable energy for the school going children.

14. A Proposal for Consolidating Initiatives and Progress Made in Developing and Offering Renewable Energy Activities to School Going Children

It is envisaged to consolidate the existing information and material on renewable energy activities/experiments/projects for developing an action plan to offer the same in schools, particularly in developing countries. It is proposed to divide the envisaged initiative into several components. While work on some of these components can be undertaken in parallel, some of them may need the outcome of other components as inputs for proper decision making. Brief description of the potential activities that need to be taken (some of these could be at a centralized level while others may need country specific focus and initiative) is presented in the following paragraphs:

(a) Review of literature that deals with the effect of exposing school going children to various challenges and issues being faced by mankind on their behavior as a citizen in future. Also to have formal and informal discussion with all stakeholders so as to ascertain (or otherwise) the specific need to provide best quality support to impart renewable energy education at school level particularly in developing countries. An attempt to seek funds to undertake activities envisaged in the first part of the study (activities outlined under ‘b’ to ‘e’ below) would then be made.

(b) Review of existing status of renewable energy education at school level (to begin with, in a select number of developing countries) with particular emphasis on the experimental and/or activity based component of the same. The countries proposed to be considered in the beginning include Brazil, China, Egypt, Sri Lanka, India, South Africa, Zimbabwe, Ghana, Philippines, Thailand and Malaysia. All possible mechanisms of information collection would be used including sending suitably framed questionnaires to obtain information from organizations involved in relevant activities and a reasonable number of representative schools.

(c) Review of all available information and material available (starting with that written in English language) that is being currently used and has the potential for use in promoting renewable energy education at school level in developing countries. Information about the modalities of facilitating and sustaining such activities in some of the developed countries would also be carefully studied with details of companies, NGOs, government organizations contributing to the same would also be collected.

(d) Using the information and material collected in (c) above, prepare compendium(s) that consolidate the collected information on experiments, activities, equipment /models that can be used to introduce renewable energy to school students. It is envisaged to have separate compendiums for children in primary and secondary schools.

(e) To obtain feedback from all stakeholders on the compendium(s) prepared. Also to organize a workshop to discuss each of the experiments and activities included in the compendium(s) and also the feedback received from various stakeholders.

(f) Preparation of proposals to seek financial support for development and trial of different experimental kits, demonstration models and equipment. It is envisaged to undertake this activity in partnership with one or potential entrepreneurs who would like to continue with the activity on self-sustaining basis in future. Work on the development of experiments, models and equipment would commence upon receiving financial support. Each of the experiments and activities will have to be tried and tested several times to ensure their efficacy in imparting the envisaged knowledge and/or skills to the school children. It is also envisaged to give demonstration in schools and/or invite school children and their teachers at a central place for their comments and suggestions.

(g) Develop manuals and leaflets for use by students as well as by teachers engaged in this activity.

(h) Short term training of teachers for trial run in the schools – if need be a set up for periodic short term training of teachers could be established in each country involved in the outreach phase of the project

(i) Establish a website that provides consolidated comprehensive information on this aspect and work out modalities of operating and updating the same on a self-sustaining basis.

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Appendix-I
Some of the Gadgets developed at Indian Institute of Technology Delhi in early 1980's to offer school level experiments

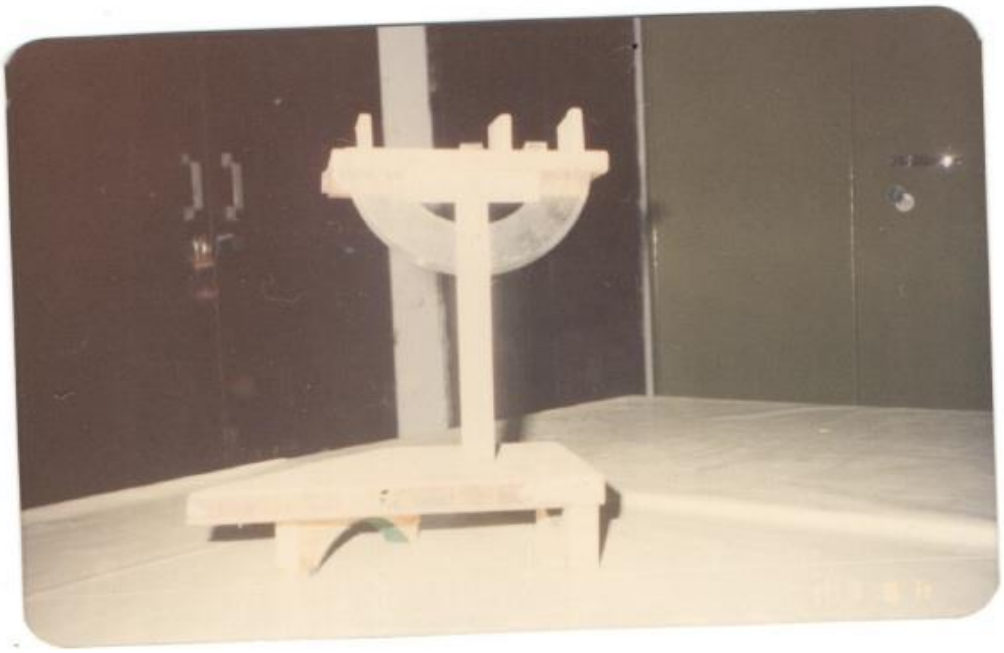

Fig. 1: Measuring altitude of the Sun

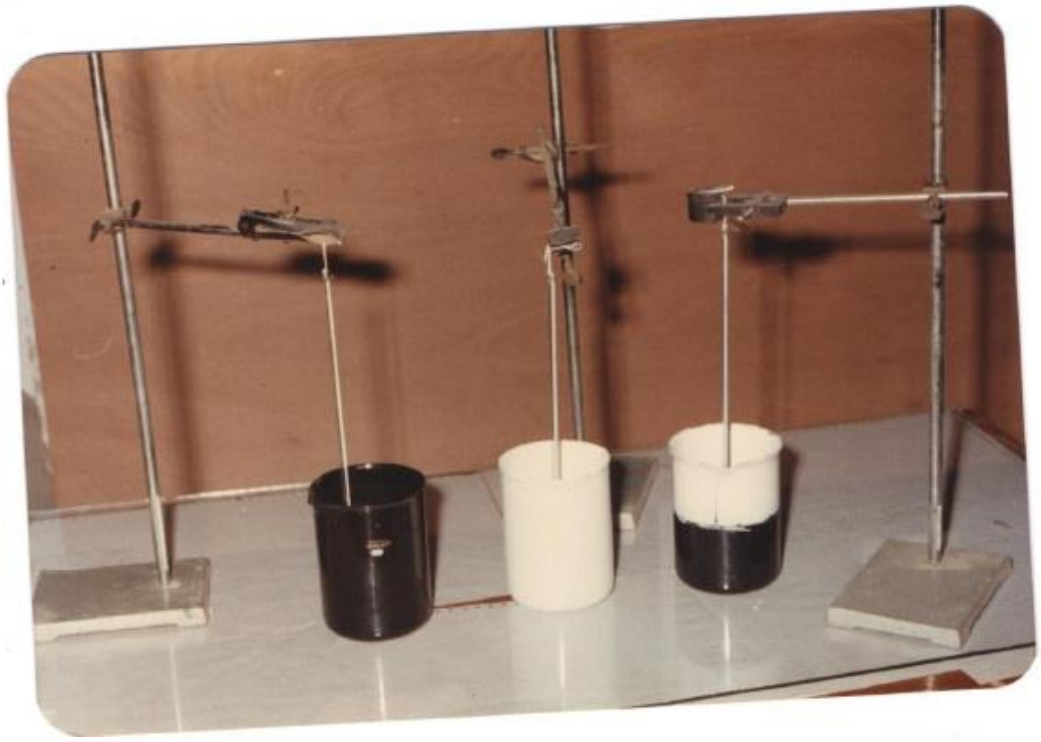

Fig. 2: Absorption of solar radiation by different colours- solar heating of water in beakers

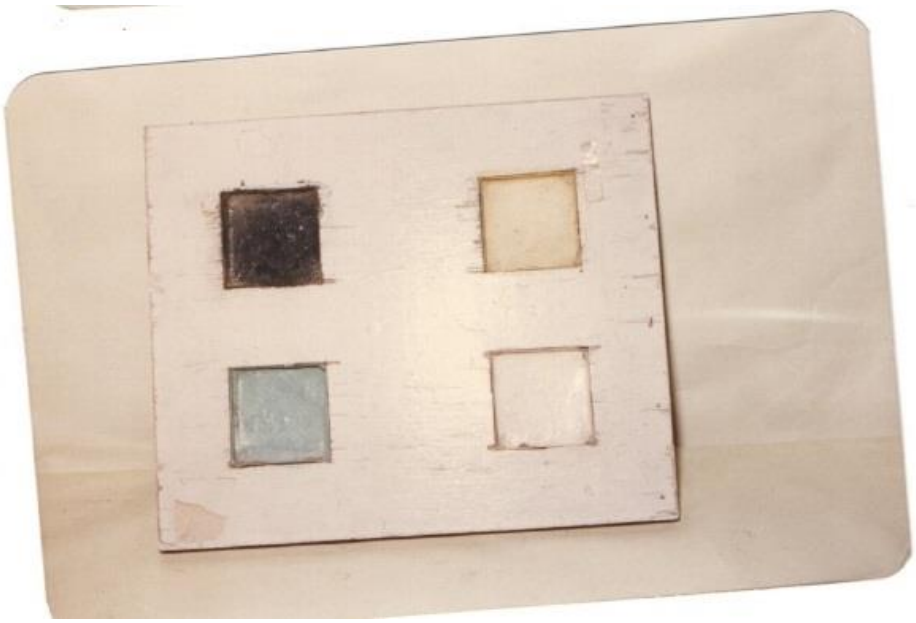

Fig. 3: Absorption of solar radiation by different colours – melting of ice cubes kept in trays coated with different colour paints

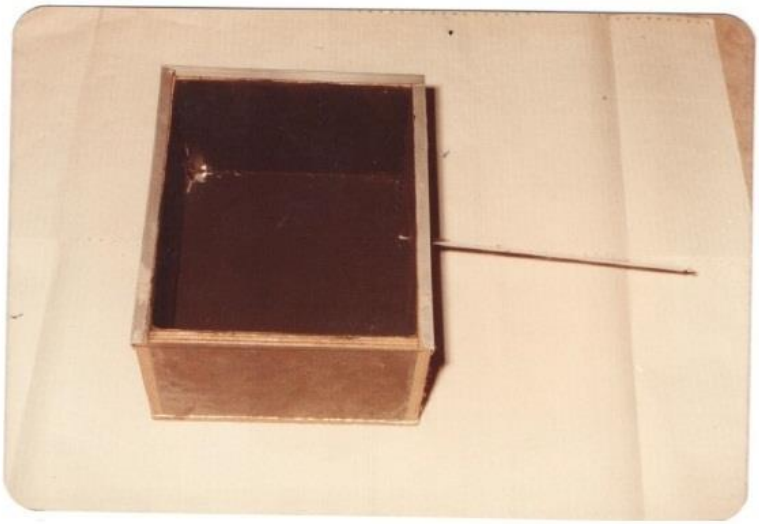

Fig. 4: Greenhouse effect

Fig. 5: Effect of orientation of the transparent wall on the enclosure air temperature

Fig. 6: Arrangement to measure reflectance of reflecting materials and transmittance of glazings

Fig.7: Movement of focal line of a linear Fresnel reflector

Fig. 8: Rise in temperature of water in the can at the focus of a conical concentrator


Fig. 9: Composite parabolic trough with a rectangular channel absorber

Appendix- II

Examples of Activities Developed and Presented in Teknoland (a Science centre in Falun Sweden) [ ]

Fig.1 A set up to demonstrate greenhouse effect being built at Teknoland

Note: A higher temperature can be experienced inside the greenhouse (as compared to temperature outdoors) demonstrating the greenhouse effect

Fig. 2 Yourself a Sun-Dial Exhibit at Teknoland

Note: Stand straight on a grey stone so your shadow points towards the white stone. What time is it? Since the sun's path over the sky changes a little from day to day, the places of the stones have to be changed from time to time. (Please don't move any stones yourself, let Teknoland's personnel do the adjustments!)

Fig. 3 Solar Heated Chess Board at Teknoland

Note: Walk around barefoot and feel the difference between black and white squares! Also play *4 against 1*.

<u>4 against 1:</u> Two players, white and grey. You play only on white squares. Place the four white pieces along one edge. Place the gray piece at the opposite edge. The players take turns in moving a place to one adjacent white square. Gray player begins. White is only allowed to move ahead, never back. Gray wins if it manages to pass behind the white pieces. White wins if white shuts up gray so it cannot move. (No piece may jump over another piece.)

Fig.4.Playhouse with PV electricity at Toddlers' Teknoland

Note: In the house there is a radio, which gets the required electricity from a solar panel on the roof. Cover the solar panel to quiet the radio.

Fig.5. Solar Surfaces Demonstrated at Teknoland

Note: Feel the different surface temperatures! A black surface absorbs more sunlight than a white or a metallic. A surface turned towards the sun than one that is turned away from the sun. Glazing prevents radiation from the surface. A painted surface radiates heat easier than a metal surface and is therefore cooler.

Fig. 6. Making popcorn using a solar concentrator at Teknoland

Note: When the sun is visible, rays directly from it can be concentrated into a small area. A reflecting parabolic mirror creates almost a point. A near-parabolic mirror like this one produces a slightly wider spot. The concentrated light gives high temperature, so with a frying pan on that spot it is possible to fry pancakes or pop popcorn.

Caution: This exhibit is dangerous and may only be handled by Teknoland's staff!

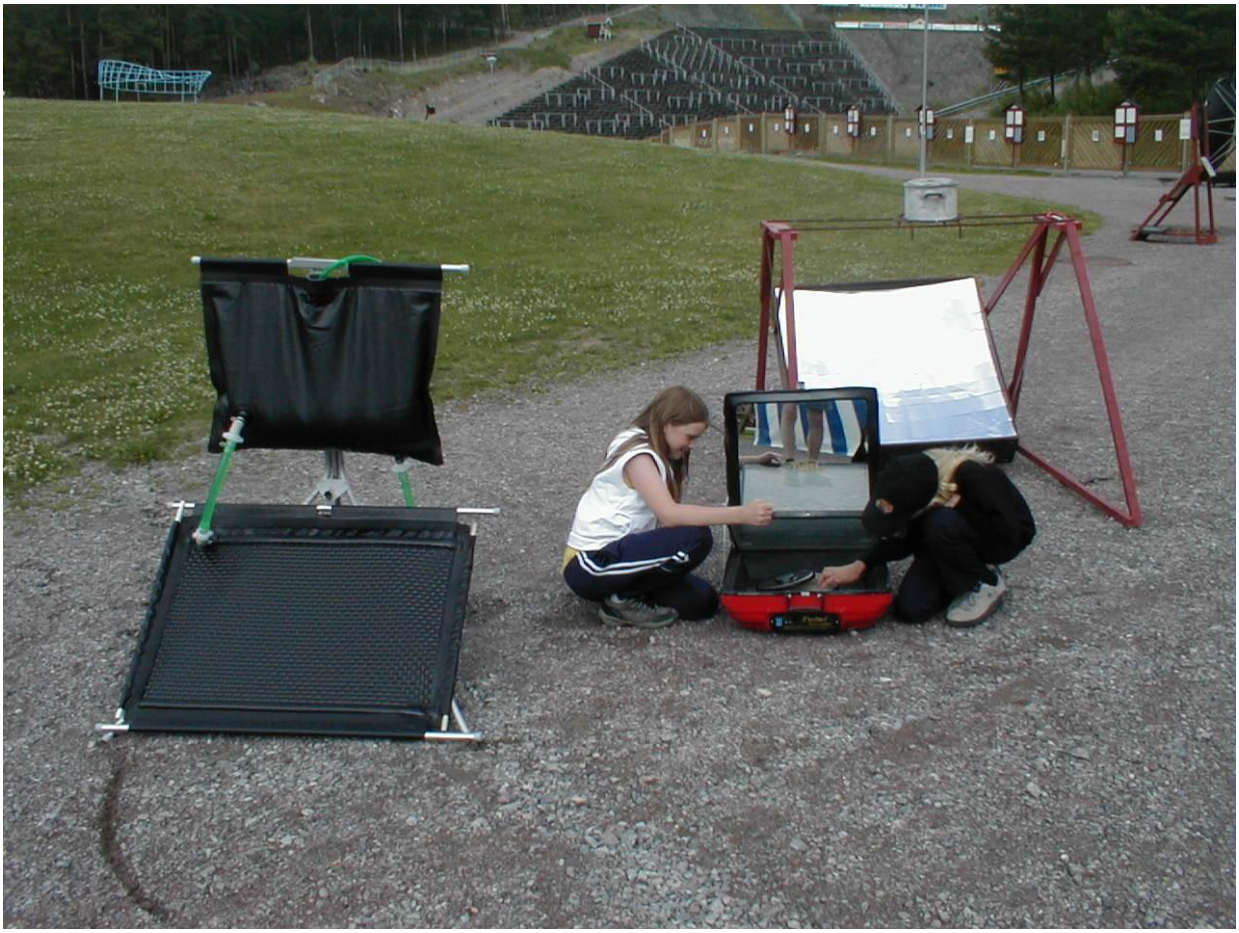

Fig. 7 Principles of solar collection and solar cooking being demonstrated to school going children

Appendix -III

15. Learning Objectives for School Students (Grades 10-12) Participating in an Activity on Bio-diesel

(a) Introduce students to a new and exciting form of renewable energy
(b) Pose a challenge to the students to apply their knowledge of sciences and mathematics in an enriching hands-on laboratory exercise.
(c) Definition of a renewable fuel
(d) Benefits of using biodiesel for substituting petro-diesel
(e) Process of making bio-diesel from waste oil (and other feed-stocks)
(f) Modalities of making bio-diesel using waste oil from different sources
(g) Chemical(s) necessary to determine oil quality and also the procedure
(h) Approach for assessing the finished products from the bio-diesel reaction
(i) Approaches for addressing waste stream management issues in bio-diesel production in an environmentally responsible manner
(j) Comparison of the cost of bio-diesel with the petro-diesel

16. Sample points for ice-breaking prior to engaging school going children in renewable energy activities

(i) Where does it get its energy? – (a) Kite, (b) Lamp, (c) Car, (d) Dog, (e) Tree, (f) Fire (g) Television, (h) Sailboat (i) mobile phone
(ii) How things have changed over time ('THEN' and 'NOW') – spoon and electric mixer; legs/horse and car/motor cycle; paper, pencil and computers
(iii) Set of Questions for a Pre-test on Fundamentals of Energy
   (a) Explain the meaning of the sentence " I do not have much energy today"
   (b) Explain the term "Energy Source".
   (c) Make a list of various sources of energy
   (d) Classify the energy sources as renewable and non-renewable.
   (e) Describe the approaches that can be used to produce electricity from different sources of energy
   (f) Explain the need for energy conservation and that of using energy efficient machines
   (g) Discuss potential approaches for meeting global energy demand in the absence of fossil fuels
   (h) Discuss the adverse environmental impacts of fossil fuels utilization

(iv) Initiate discussion with one or more of the following questions:
   (a) What is energy?
   (b) Why produce electricity?
   (c) How electricity is produced?
   (d) Why is it important not to waste energy?
   (e) What can be used to substitute energy?
   (f) How many ways are there to save energy?

(g) Where does all energy come from?
(h) What are the most commonly used energy sources in USA? In India? In Tanzania?
(i) In what sense the Sun is the primary source of energy?
(j) How renewable sources of energy are different from non-renewable sources of energy?
(k) Do electrical appliances save time? Does using electricity make life easy and convenient for human beings?
(l) What are the risks and precautions while using electricity?

17. Using an Exercise Involving Fill in the Blanks to Assess the Knowledge Gained by School Going Children through Activities and Other Modes of Interaction (or to use this as an activity itself)

Each of the students (school going children at secondary or senior secondary level) is given a sheet with statements having blanks in between. The students are then asked to fill in each of the blanks by choosing one of the words out of a set of words given at the end of the sheet. The students are often instructed to fill only one word in each blank and also that each word in the set can be used only once.

To begin with, the teacher provides a brief introduction to the task to be undertaken. The sheet is then distributed to the students with a pre-defined time limit for completing the exercise. At the end of the stipulated time one of the students is asked to read the first completed statement and also to justify his/her choice of the word for filling in the blank. Another student is then asked to comment on the choice of word made by the previous student and so on until a consensus for a correct choice is arrived at. A similar approach is followed to discuss all the statements in the sheet.

An example set of statements with blanks and the corresponding set of words is given below:

(i) Statement with Blanks

(a) Water in the gaseous form is called ----------.
(b) Natural movement of the air around the earth is called ----------.
(c) Warm air ---------- into the atmosphere.
(d) During the day, near the shore of an ocean the air over ------ heats up faster than air over ---------.
(e) When water turns into gas it ----------.
(f) ---------- moves water from higher to lower levels.
(g) Rain and snow are called ----------.
(h) Wind turbines convert the energy in moving air into ----------.
(i) ---------- is a measure of electricity.
(j) A ……cell converts light into electricity.
(k) Plants take in solar energy and store the same in their leaves and roots as --------- energy.
(l) White and shiny objects -------- solar radiation falling on them.
(m) Solar energy is called a ------ energy resource because it is expected to be available for practically infinite time for human beings.

(ii) Set of Words to Fill in the Blanks

Reflect; Joule; Phot/Solar; Land; Water; Rises; Air; Precipitation; Water-vapour; Chemical; Renewable; Electricity; Gravity; Evaporates

18. Activity Designed to Help Students Research, Understand, Analyze and Evaluate Concerns about and Opposing Viewpoints to Harnessing Renewable Energy

(a) Key questions: (i) why some individuals, groups or organizations oppose harnessing of renewable sources of energy? (ii) What shapes the perceptions of public about different energy supply options and associated technologies and how?

(b) Learning Outcomes: on successful completion of the activity a student will be able to: (i) assess diverse perspectives about renewable energy resources and their harnessing, (ii) synthesize information collected on opposition to harnessing of renewable energy sources, (iii) identify sources of relevant information and assess their reliability

(c) Assessment: The students may be asked to prepare a write-up that summarizes their understanding about opposition to renewable energy utilization

For example, the students may find out that the reasons for opposition of initiatives towards harnessing renewable sources of energy include: (i) insufficient knowledge about renewable energy resources and technologies, (ii) concern about potential adverse economics, environmental and safety related impacts of harnessing renewable energy sources on the immediate neighborhood, (iii) lack of trust in government and/or industry, (iv) perceptions and beliefs about advantages and disadvantages of using renewable energy technologies.

19. Example of an Activity Kit

A renewable energy education set (Junior Science Experiment Kit) is offered by M/s Horizon Fuel Cell Technologies that essentially consists of a modular experimental set designed to demonstrate the working of renewable energy technologies on a miniature scale. As an example, one of these sets contains components of a wind turbine, solar cell panel, fuel cells and loads with associated other hardware and software to facilitate experiments/activities by a group of four to five students. The experiments/activities that may be offered with the set include:

- Study of effect of heat, shade and tilt angle on the performance of solar panel and also determination of its maximum power point
- Studying the effect of number of blades, shape of blades, angle or pitch of blades on the performance of the wind turbine
- To produce hydrogen by electrolysis of water
- Generating electricity achieved using hydrogen produced from electrolysis of water in a fuel cell
- Building solar or wind farms
- Designing systems for meeting the energy requirement of the school