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Science Curriculum for Distance Learners: A case for Teaching Energy Studies

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Energy has become a topic of discussion in all walks of life after the energy crisis of the early 1970's. The proper management of energy resources has become vital since the fossil fuels, on which the global energy scene mainly depends, are going to be extinct very soon. Though the various Government and Non-Government agencies in India have been trying to focus the attention of the society on energy related issues through various means of mass media, yet the impact of this effort has been very small. So far not much effort has gone towards educating students in schools and colleges in issues pertaining to energy. Except for a few courses of highly specialized nature offered mostly at postgraduate level and a brief mention in the 8th and 10th standard NCERT science text books there is no course on 'energy' being taught in the country. In view of the importance of this thrust area, it is proposed that energy related topics be included in science curricula both at the school and the university levels. To begin with, it is suggested, that the Indira Gandhi National Open University (IGNOU) and the National Open School (NOS) may take a lead in this direction, and may act as pace-setters for coventional universities and schools to follow. In this paper two model curricula on 'energy' are also proposed.

Evolving integrated curricula in high priority subject areas is indeed a pressing issue for the distance education professionals today. This article answers this need through addressing the necessity to concentrate on energy studies as an integral part of the science curriculum at both the school and university levels in the open system. Concerted arguments for the case are accompanied by a brief review of the lapses in the present situation. Here is something for science faculties in open institutions to think on.

INTRODUCTION

Energy is an essential component for mankind's existence on the earth. The development of human race is a direct consequence of its technological ability to convert various forms of energy available on earth into their useful forms. Early man's energy needs were met either directly by absorption of solar radiation or through food. A new dimension in energy requirement got added when man learnt to make fire. As man's energy needs still kept on increasing, he tried to find new sources of energy like animal power, fuel wood, wind and water. This scenario continued for several centuries till the invention of steam engine and the discovery of electricity in the 18th century. Versatility of both these changed the traditional agricultural pattern of life style to an industrial pattern. In the process traditional sources of energy like fire wood/ animal power etc. got replaced mainly by commercial sources like coal, electricity, petroleum and natural gas.

The race for industrialization in the last hundred years has increased the man's energy requirements to such an extent that he has started exploiting energy sources at a rate which our wonderful planet, earth, can no longer sustain. However, the changed global geo-political scenario has made the man well aware of the bottom line of the fossil fuel (coal, petroleum and natural gas) reserves, which have become scarce and costly. Nuclear energy was once thought to be an ultimate answer to the problem of future energy needs of the mankind. However, it has been realized that nuclear energy creates more environmental problems than it solves the energy problems itself.

For the survival of mankind it has become imperative to search and exploit renewable energy sources like solar energy, wind energy, etc. In the world a lot of research and development activities are going on to commercially exploit various forms of renewable and environment-friendly energy sources. In India some centres of higher learning like the IITs and a few scientific organizations are training a hundred odd research scientists and engineers in this thrust area every year. In a country of more than 850 million people where nearly 100,000 villages are still not electrified and may not be connected to electricity grid for another couple of decades for various reasons, this trained manpower is highly insufficient.

In spite of the efforts by some governmental and non-governmental organizations through electronic and print media only a very small fraction of our population has been made aware of the use of renewable energy sources and of the need for energy conservation. It appears to the authors that for creating general awareness among the public, students at various levels may be treated as message transmitters and as potential future users of renewable energy sources. Unfortunately, this vast human resource in the form of students has been nearly completely ignored by our educational planners and administrators for this purpose.At present most universities and educational boards in the country do not impart education on various aspects related with energy specially with renewable forms of energy. Except for specialised M.Sc./M.Tech./M.Phil. and Ph.D. programmes offered by a few academic institutions there is hardly any mention about 'energy studies' in the syllabi of most Boards/Universities in the country.

If at all there is any mention like the one in the 8th and the 10th class science texts of the NCERT, it hardly makes the students aware of the need of energy conservation or of the ways to use renewable energy sources. It surely does not tell the students that we are overusing our resources and that we are slowly heading towards an acute energy crisis. Further, it does not bring to their notice that to import energy in the form of petroleum the country has to spend the much needed foreign exchange. It is surprising that such a vital factor, on which our own and in turn the country's survival depends, has been nearly completely ignored by our educational planners in their syllabi/curricula. Looking into the importance of 'Energy Studies' as a subject it appears that there is an urgent need to make such studies a part of science curricula both at the school and at the university levels. If this is done, it is hoped that the knowledge regarding techniques for using renewable energy sources will easily percolate down to the users even in remote and difficult rural areas where the need for such sources is maximum.

By the turn of the century, our fossil fuel reserves would have depleted further. Our population explosion and industrial development would have increased our energy requirements manifold making energy as one of the most burning questions of our times. In short, in our opinion, we have to make a beginning now if we have to take the country out of the most precarious situation into which it is sliding. Our emphasis now should be to introduce 'energy studies' at much greater depth both at the Senior Secondary (+2) level in schools and in undergraduate science courses in universities. Since most of the energy related topics can be understood easily by science students, it is easier to introduce these directly into the existing science courses taught in universities/schools.

Energy Scenario

On the global scale during the 100 years between 1875 and 1975, whereas the population has grown by a little more than three times from 1.2 to 3.97×10^9, the energy consumption in this period has increased more than 30 times from 250 to 7877×10^6 tons of coal equivalent per year (tce/year). Distribution of primary energy sources and the energy consumption pattern between the nations is highly uneven. The developed and highly industrialized countries supporting a small percentage of world population consume a highly disproportionate share of energy. More than 55% of world's energy is consumed by only 18% of the world population living in developed countries of Europe, USA and Japan; 52% of the world population living in the poor countries of Africa, Asia and South America uses only 15% of world's energy; while China, CIS and the East European countries having nearly 30% of world's population consume the remaining 30% of energy.

Indian energy scenario is not very optimistic. More than 850 million people live in an area of about 3.28×10^6 km^2. Per capita consumption of commercial energy in India is about 200 kg of oil equivalent (kgoe), which is amongst the lowest in the world. This may be compared to a consumption of 3000-9000 kgoe in some of the developed countries. In rural areas this parameter of development is nearly 1/3 of its value for urban areas. Not only this, we have the perennial problem of shortfall in electricity generation. On the other hand, due to large scale industrialization the annual commercial energy consumption in the country has increased three times over the last two decades and cannot be met by its own resources. The country has to spend a lot of foreign exchange to provide this energy through oil imports. This is the situation when the country is spending more than 30% of its total budget expenditure on the energy sector alone. It is not unreasonable to expect that with further development and growth in the economy, energy consumption in India will increase further.

Assuming that our energy demand and supply patterns remain unchanged, we would need (Tata Energy Research Institute 1990) 186 million tons (MT) of oil, 626 MT of coal and 175 million m^3 per day of natural gas besides 85000 MW (limiting generation capacity) of primary electric power (Hydro and Nuclear only) by the year 2009-10, whereas the supply is officially predicted to be only 70 MT of oil, 426 MT of coal and 85 million m^3 per day of natural gas. To meet the shortfall by imports the foreign exchange requirements will amount to Rs. 86,000 crores evaluated at 1989 prices, which is equal to the cumulative outflow of foreign exchange for petroleum for the period 1973-88.

The Tata Energy Research Institute (TERI) predictions (1990) of energy supply and demand for the year 2009-10 under three different scenarios are shown in Table 1. In the first — *the business as usual scenario* — based on past trends and a five percent annual growth rate of G.D.P. the total annual commercial energy demand works out to 600 million tons of oil equivalent (mtoe) in 2009-10. In the second — *the low conservation scenario* — which presumes a reasonable increase in efficiency of thermal power generation and distribution, and the use of solar photovoltaic power for lighting in rural areas, the energy demand works out to be 446 mtoe in 2009-10. The third — *the high conservation scenario* — includes the options of wind and solar thermal power for electricity generation, solar cookers and hot water systems, improved cookstove adoptions; high efficiencies in industry, lighting technology and electric power generation and distribution.

The energy demand works out in this case to a much lesser value. Yet the foreign exchange required will be nearly Rs. 29,000 crores evaluated at 1989 prices. This amply goes to suggest that we have not only to adopt the various measures included in high conservation scenario but also to identify energy efficient technologies, fuel substitution options, renewable energy sources, for further decreasing the burden that the energy sector is likely to place on the balance of payments.

Table 1 : Future energy scenarios (in 2009-10) as predicted by Tata Energy Research Institute

Energy Source	Demand			Supply
	Scenario			
	I	II	III	
Coal (in MT)	626	604	508	426
Petroleum (in MT)	186	126	108	70
Natural Gas (in million m^3/day)	175	85	85	85
Primary electric power (Hydro and Nuclear only) (in Trillion Watt Hours)	217	319	319	319

I : The business as usual scenario
II : The low conservation scenario
III : The high conservation scenario

The energy scenario of India may look completely changed if we could supplement the conventional energy sources with non-conventional and renewable energy sources like solar, wind, biomass, tidal, etc. If we could collect only 1% of the total solar energy incident on India and only 60% of it may be utilized at an average efficiency of only 10% then this can make available 360 x 10^{10} kWH of energy. Similarly on the basis of wind energy potential of India, 1,00,000 wind mills of 100 kW peak power output if installed by the year 2000 may generate 30 x 10^{10} kWH of electricity. Non-commercial energy sources like biomass (dry wood, agricultural waste, animal dung, etc.) can also produce nearly 200 x 10^{10} kWH of energy. Thus if people are made aware of all this, and are taught the relevant uses and technologies, the whole energy scenario of the country may be altered.

We all know that fuels consumed in our households, industry and transport add noxious gases in our atmosphere. These lead not only to health problems, but also to problems like acid rain and smog. The TERI has predicted (1990) that with increased usage of fuel efficient technologies and renewable energy sources, a reduction may also be achieved in the emissions of these toxic gases (Table 2). It is thus clear that continuing on the present path is neither feasible nor advisable.

Table 2 : Emissions from energy consumption (in 2009-10) as predicted by Tata Energy Research Institute

Scenario	Emission (in MT)				
	CO_2	SO_2	CO	NO_x	Parti-culates
Low Conservation	1758.2	7.4	4.2	3.9	0.8
High Conservation	1472.4	5.6	4.2	3.0	0.8

Energy Education in India

Energy as a discipline for education is still in an infant stage, born after and as a consequence of the 1973-74 energy crisis. It is inter-disciplinary in nature and requires understanding and knowledge of social, physical, technical and biological sciences.

Till 1975, energy topics did not form part of education at any level in India. The first initiative in this direction was taken at the Indian Institute of Technology, Delhi by setting up a Centre of Energy Studies. This Centre was the first to offer M.Tech. and Ph.D. programmes in the country (Garg and Kandpal 1992). The Indian Institutes of Technology at Bombay and Kharagpur followed suit by starting M.Tech. and B.Tech. courses, respectively.

Jyoti Solar Energy Institute at Baroda attached to Birla Vishvakarma Mahavidyalaya offers an elective course on Alternative Energy Sources to final year undergraduate engineering students. A one year diploma course on Solar Energy is offered to science/engineering/agriculture graduates by Sardar Patel University, Vallabh Vidyanagar. The School of Energy Studies, Devi Ahilya Vishwa-vidyalaya, Indore imparts training in M.Tech. in Energy Management, and Post Graduate Diploma programmes in Renewable Energy, Energy Conservation and Energy Planning. The Guru Nanak Dev University, Amritsar offers an M.Sc. Applied Physics course AP-123 on Solar Energy. Madurai Kamraj University, Madurai offers an M.Sc. course on Energy Studies and an M.Phil. course on Energy and Environment. Besides these specialised post-graduate courses, the only other levels at which energy topics are taught are the middle level (class 8) and secondary level (class 10) in schools following the CBSE syllabi. The NCERT science text books meant for 8th and 10th standards have new chapters dealing briefly with energy topics. No other university or college in the country, to our knowledge, is offering any other course on aspects related with energy.

An overall review of the concept and scope of energy education in the country leads us to the conclusion that energy being one of the most fundamental realities of human life for its survival, its education must form the real core of educational curricula. In fact energy education must be a continuous life long exercise beginning at the primary level and continuing through all stages of formal and non-formal education. The authors feel that specialized training offered by a few institutes of higher learning in the country to a few selected scientists and engineers is highly inadequate and that energy education should be imparted to all the students at different levels. Energy topics should be incorporated into science, social science, engineering and agriculture courses. Their inclusion, particularly in physics and engineering courses should pose no problem as the concepts involved are quite related. Attempts may be made to introduce 'Energy Studies', as a separate paper in science and engineering courses at the graduate level. It is through energy courses that our younger generation will acquire awareness and knowledge, and will develop proper attitudes, skills and abilities to solve real life problems of daily life.

Why by Distance Mode?

Though the development of alternative and renewable sources of energy is a thrust area for research in our country, yet the fruits of this research are not reaching the very people for whom these sources of energy have more relevance at the moment. These are the people who live in remote, rural and tribal areas, far from the national electricity grid. The authors feel that in the beginning it will be more difficult to induce people in urban areas to use alternative/renewable sources of energy where the energy supply from commercial sources is already available.

If the people in rural and remote areas are made aware of the dire need to conserve energy, and the ways and means to use alternative/renewable sources of energy, there is no reason to think that these people will not use such sources provided they are clean and economically viable. It is in this national endeavour of educating such people that the distance eduction can play a big role.

The distance education has made many strides in the last couple of decades and has established itself as a more powerful and flexible system of education (Kulandai Swamy 1992) which can easily surpass the geographical boundaries of the conventional system. The main aim of this system of education is relevance. It is meant to look after the interests of disadvantaged people. It is with this background that this mode of education can be used to play a vital role in manpower development in this area, to save the country from sliding into a slumber.

Proposed Curricula

The main objective of any desirable curriculum on energy is to inform the learners about the various types of the sources of energy, the extent and location of their availability, their present stock, their expected life time, the present technologies for harnessing them, the ways to conserve energy and the impact on environment. In general, the curriculum at any level may be flexible and may be chosen keeping the target learners in mind. A curriculum on energy, for example, for physics students may provide emphasis on the physics of conversion of primary energy forms to the usable forms, and on their respective technologies.

We in this paper propose two syllabi on 'Energy Studies', one (Appendix-1) for IGNOU's Bachelor's degree programme in science (Kumar and Garg 1992) and the other (Appendix-2) for the Senior Secondary science course of NOS. The syllabus meant for IGNOU is for an Application Oriented Course worth 8 credits. It is interdisciplinary in character, and can be easily incorporated into the existing curriculum because of the proximity of concepts involved. The syllabus for NOS is worth 4 chapters, 2 in physics, 1 in chemistry and 1 in biology. It is hoped that with the introduction of these courses for distance learners, a new beginning will be made in our country with far reaching consequences.

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APPENDIX I*

Natural resources: Non-renewable — Land and minerals (fossil fuels, metals, radio-active elements), Renewable — solar radiation, hydrogen, biomass, water and ocean, wind, geotherms.

Energy scenario
Global and Indian energy scenario in terms of potential, production and consumption. Energy in daily life, difference in rural and urban energy scene.

Non-renewable energy resources
Fossil fuels: Coal, petroleum, natural gas, their origins, amount and life of world and Indian reserves. Energy crisis and their efficient utilization. Impact on environment, acid rain and global warming.

Nuclear: Fission and fusion, related technologies, breeder reactors, their relevance for India, nuclear waste disposal, peaceful and defence applications, environmental impact.

Renewable energy resources
Solar energy: Measurement and estimation of solar radiation, heat transfer-conduction, forced and natural convection, laws of black body radiation. Solar thermal devices — low temperature (water and air heaters, crop dryer, cooker, water stills), medium and high temperature (for electricity generation). Cooling by solar energy. Solar photovoltaics, principle of solar cells, types — monocrystalline, polycrystalline and amorphous, technology and applications, solar energy storage, solar architecture. Economics of solar energy.

Hydro power: Mega, mini and micro hydal power plants and their environmental impacts.

Wind energy: Wind data of India, technologies, applications of wind mill and wind electric generator.

Biogas: Aerobic and anaerobic bioconversion processes, calorific value and composition of biogas, biogas plant technologies and status, environmental impacts.

Biomass: Production and utilization through various conversion routes — biological, chemical and thermo-chemical. Wood, charcoal, improved chulahas (cookstoves), agro and forestry residues. Environmental impacts.

Geothermal energy: Potential in India, hot springs and steam ejection, power generation, environmental impacts.

Ocean energy: O.T.E.C., tidal and wave energy, principle, potential, present status and environmental impact.

Future energy sources: Hydrogen, MHD and Petrocrops.

Energy conservation: In transport, industrial, agricultural and domestic sector.

Energy auditing and management: Cost/benefit analysis.

Resource estimation and management: Remote sensing, resource maps, control of population, concept of Green GNP, conservation of natural resources.

APPENDIX II

Physics
Energy: Renewable sources — solar energy, wind energy, hydro power, ocean energy (O.T.E.C., tidal, wave), biogas, biomass. Non-renewable sources — fossil fuels (coal, petroleum, natural gas), nuclear materials. Indian energy reserves, environmental impact, energy crisis, energy conservation (transport, domestic, agriculture). Economics of energy.

Electricity: Generation (hydro, thermal, nuclear), transmission, conservation.

Solar energy: Solar radiation, low temperature solar thermal devices (cooker, water heater, air heater, crop dryer, stills). Solar cells, solar energy storage.

Wind energy: Wind mill, wind electric generator.

Chemistry
Fossil fuels: Origins. Coal-gasification, lignite, grading, applications, pollution. Petroleum-refining products, uses, petrochemicals. Natural gas-composition and applications.

Biology
Biogas: Biogas conversion progress, composition, biogas plants, uses.

Biomass: Wood, charcoal, agro and forestry waste, utilisation through various conversion routes (biological, chemical, thermo-chemical). Improved cookstoves.

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