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Renewable Energy Research in India

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August 1981

RENEWABLE ENERGY RESEARCH IN INDIA

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FOREWARD

If man is to continue living on the thin skin of our small, vulnerable planet, it is imperative that he learns the use and re-use of those of the earth's natural resources which are renewable. Research into our renewable energy sources, therefore, is an integral part of all future energy planning, both at the national and international levels. And in this day of a crowded, technically-linked world, there is a high degree of optimism that at least some of this innovative research will prove to be of global significance and benefit.

In India, the renewable energy research programme has gathered momentum during the last six years. Many national laboratories, higher technological institutions, universities and industries — private as well as public — have now entered this field; and the document presented here, 'Renewable Energy Research In India', is a compendium of the progress reports received from as many as 70 organisations spread over the country. We are indeed grateful to them and their scientists for their contribution, and any work inadvertantly omitted here will find a place in our subsequent editions.

Tata Energy Researh Institute is proud to offer this compendium -- a companion volume to the Directory of Solar Energy Research Projects in India -- in the hope that it gives a panoramic view of what has been achieved in sun-rich India.

D S Seth

(D . S . Seth)
Vice Chairman
Tata Energy Research Institute

14 August, 1981.
Bombay.

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COMMISSION FOR ADDITIONAL SOURCES OF ENERGY

Government of India

New Delhi

Recognising the need for a well-coordinated approach to develop new and renewable sources of energy and to accelerate the pace to attain self-sufficiency in energy, the Government of India recently established a separate Commission for Additional Sources of Energy (CASE), with full executive and financial powers.

CASE will be responsible for formulating policies and programmes for the development of new and renewable sources of energy; coordinating and intensifying research and development activities and taking conscious steps for commercial exploitation of the technologies already developed or being developed; and for ensuring implementation of Government's policies in regard to all matters concerning new and renewable sources of energy.

More specifically, the Commission will plan, initiate, financially support, monitor and undertake integrated research and development programme in the areas of solar energy, wind energy, biomass, decentralised energy systems, etc. The Commission will advise the Government on import of technology and operate all necessary industrial and licensing policies and procedures in this area. It will also be responsible for international co-operation and for recommending various incentive measures for production and utilisation of new and renewable energy products, devices and systems.

Members of the Commission are:

Prof. M.G.K. Menon, Secretary, Department of Science and Technology	...	Chairman
Shri D.V. Kapur, Secretary, Department of Power	...	Member
Shri V.B. Eswaran, Secretary, Department of Expenditure.	...	Member

Dr. D.P. Gautam
Director General, Indian Council of Agriculture Research ... Member

Shri A.M. Thomas,
Chairman, Khadi and Village Industries Commission ... Member

Shri Maheshwar Dayal,
Adviser, Department of Science and Technology. ... Secretary

"SIXTH" Five Year Plan:

The Government has accorded top priority to the energy sector during the Sixth five-year plan (1980 - 85). It recognises the importance of energy conservation and the need to develop new and renewable energy sources. The plan represents a strategy encompassing the following objectives:

1. To implement on a large scale, programme such as those of energy forestry and biogas technology.
2. To carryout field testing and demonstration of technologies which have the potential to become commercially viable in the next 5 to 7 years; and
3. To intensify R & D of other technologies that would become commercially viable in the near long term.

Plan Outlay

The Sixth plan envisages a significant increase in the allocation for research, development and demonstration programmes. An amount of Rs. 400 million has been allocated for this purpose in the years 1980 to 1985 in addition to Rs. 100 million for a project relating to Magneto-hydrodynamic (MHD) power generation and other new technologies based on coal. The significant increase planned in this area may be judged by the fact that the outlay during the first year of the plan (1980 - 81) was Rs. 22.5 million (revised to Rs. 24 million) while the outlay for the second year has been proposed at Rs. 70 million. A separate allocation of Rs. 500 million has been made in the plan for schemes on fuel and farm forestry.

Incentives, Subsides

The government proposes to promote the wider utilisation of renewable energy systems through various incentives, subsides etc. The Sixth plan provides for Rs 500 million to be spent on subsides and some supporting facilities for the establishment of family biogas plants. The Government has already announced an enhanced depreciation allowance at 30% on machinery or plant installed for manufacturing renewable energy devices and systems; and a similar enhanced depreciation allowance on renewable energy devices or systems used for business or profession. Government has also exempted excise duty from devices and systems designed to use solar, biomass and wind energy. Access to loans from banks and other financial institutions are also accorded the same terms and conditions as are applicable to other priority sectors.

It is expected that the Commission will gear up soon to direct the activities because of the infrastructure already built by the Department of Science and Technology. The tenure of the members of the Committee (for CASE) is upto 31 March 1983.

DEPARTMENT OF SCIENCE AND TECHNOLOGY

New Delhi

The development of new and renewable energy sources has now become one of the important activities of the Department of Science and Technology. The programme undertaken by the Department covers research, design, development and demonstration activities, as well as the promotion of public awareness of the potential contribution of new and renewable energy sources. The Department carries out this programme with the active participation of research and educational institutions, industry, user agencies and extension organisations. The budget for the year 1980-81 was Rs.2.25 crores, which was revised upwards to Rs.2.40 crores. A separate programme on research and development in the field of MHD is also being implemented by the Department.

Some of the major developments during 1980-81 have been:

1. Establishment of a Commission on Additional Sources of Energy with DST being the implementing department;

2. Formulation of a significantly increased programme for the Sixth Plan 1980-85;

3. Acceleration of the entire programme relating to new and renewable energies through the initiation of significant demonstration and field installation projects in the areas of solar energy, biogas and wind energy. In 1980-81, the programme was stepped up by 60% over the previous year. The Annual Plan for 1981-82 will be three times that of 1980-81.

Details of the activities of the Department, during 1980-81, in some specific areas are given below.

SOLAR ENERGY

The Department expanded its activities in the areas of solar thermal

applications and solar photovoltaic technology. Efforts made in this area during the past few years have led to the development of technologies which are in a stage suitable for demonstration and subsequent commercialisation.

Solar Thermal Devices and Systems:

1. Collectors and Water Heating Systems: Knowhow generated under DST's programme with regard to mild steel flat plate collectors and water heaters is being commercialised, and some manufacturing licences have already been taken up by different units. A major demonstration programme for wider application of solar water heating in domestic, industrial and commercial establishments has been initiated. In addition to the water heating facility already established at the Qutab Hotel, New Delhi, such systems are being set up at the District Leprosy Hospital, Pune, a textile mill in Ahmedebad and for sericulture operations in Karnataka. Work has been initiated on the establishment of solar water heating systems in a dairy at Warangal, a bakery in New Delhi and in a few other locations. Additional locations are being continuously added. R&D work on advanced flat plate collectors, selective coatings, and concentrating collectors has made good progress. Test facilities for solar collectors are being established at NPL; research projects on the development of shallow solar ponds, medium temperature, tracking and nontracking collectors, thermal modelling systems etc. are under progress.

2. Drying Systems: On the basis of the experience gained with the systems developed so far, a 30 ton per day paddy dryer is being installed at Alathur (Kerala) and a ½ ton per day cash crop dryer at Agartala (Tripura). The performance of the grain dryer at Ludhiana, paddy dryer at Annamalainagar, cash crop dryer at Gauhati, milk dryer at Anand and solar timber kiln at the Forest Research Institute, Dehra Dun, which had been installed earlier, is being monitored. Work is in progress on the design and development of a solar veneer dryer for plywood factories and on solar tobacco curing. Efforts are being made to evolve standard designs for drying of various agricultural commodities in different quantities under varying agro climatic conditions.

3. Airconditioning and Refrigeration Systems: The performance of the ½ ton capacity cold-storage unit at I.I.T, Bombay and other experimental cold storage units in the country is being monitored. Designs have been completed for a 10 ton cold storage plant based on solar energy. A demonstration unit has been initiated at a State farm; additional commercial size field units will be installed in the next and subsequent years.

4. Other Studies: R&D work on prime movers is in progess. A small stirling engine has been fabricated (I.I.T., Bombay) and is being tested. A demonstration power plant for decentralised applications is being installed at Hyderabad. Pilot projects on decentralised integrated energy systems, based on point or line focussing concentrating collectors to be coupled with biogas, wind energy or vapour absorption refrigeration systems are being taken up. Some solar desalination units have been installed for field trials. A solar radiation data handbook has been published under the sponsorship of the Department. The handbook is expected to be of considerable use to solar energy system designers and users in India. A demonstration project for possible solar cooling/heating of houses has been initiated. In order to promote the large scale application of solar thermal technology, the Department has formulated a comprehensive project for the establishment of a Product Development and Analysis Centre, and advance action on this has been initiated.

Solar Photovoltaic Technology:

In this area, the level of production of solar cells has been increased. Efforts are under way to develop and indigenously produce solar grade silicon, improve the progress technologies and efficiencies of solar cells and thereby bring down the costs.

1. Demonstration Programmes: Solar photovoltaic modules have been installed as demonstration systems in the light house beacons at Dwarka Port, for pumping water in the solar distillation plant at Avania village in Gujarat, of drinking water supply at Tijara village in Rajasthan, etc. A community lighting system has been installed at Choglamsar Village in Ladakh by Central

Electronics Limited. A short term programme has been drawn up for fabrication and demonstration of modules of 25 kW aggregate capacity for pumping and 5 kW capacity for other applications. Pumps operated on photovoltaic modules have been installed at Punjab Agricultural University, Ludhiana, Indian Agricultural Research Institute, New Delhi and the premises of the Department and of Central Electronics Limited, Sahibabad. Additional units are under installation at agricultural universities in Gujarat, West Bengal and Haryana as well as at the Central Inland Fisheries Research Institute, Madras Centre, the Press Enclave Residential Colony, New Delhi and in Mizoram and Ladakh. The programme is being accelerated to install such pumps at a variety of new locations during the next financial year. Among other applications of photovoltaic systems being developed are those related to educational radio and TV sets, cathodic protection of oil pipelines, power for communications equipment, etc.

2. Pilot Plant Facility: A major project has been drawn up for establishing pilot plant facilities under CEL to achieve a production capacity of 1 MW per year in 5 years. The project is to cover large scale application of photovoltaic systems in rural areas (with emphasis on water pumping); it is expected to cost about Rs.12 crores. Advance action by way of procurement of materials and equipment has already begun. Planning for larger commercial scale plants has also been initiated.

3. Other Photovoltaic Programmes: A scanning Auger spectrophotometer facility with accessories has been set up at IIT, Delhi for research on thin film solar cells and selective coatings. The Department is also supporting research work on thin film cadmium sulphide solar cells, polycrystalline solar cells, extraction of silicon from rice husk, concentrator solar cells, etc.

WIND ENERGY

The Department has continued its efforts to evolve cost-effective designs of wind mills for various applications. Following the development of a horizontal axis sail type wind mill, work has been initiated for the installation

of 10 prototypes at selected locations. Prototypes of vertical axis wind generators installed at Kalpakkam and Saurashtra University are undergoing performance monitoring. R&D projects on the development of a 250 W multiblade wind mill and twin turbine vortex wind mill have also been initiated. A widespread field demonstration programme is under implementation to get experience for large scale application. Plans for setting up two wind energy centres have been finalised.

HYDROGEN AND CHEMICAL SOURCES OF ENERGY

Certain basic investigations carried out under a project for hydrogen production by photo-chemical methods using solar energy appear to show promising results. Greater emphasis is proposed to be given to studies relating to the storage and utilization of hydrogen. Projects on nickel-iron and metal air batteries and other areas of energy storage have been initiated. The project for the development of a ½ ton commercial battery powered vehicle is continuing. The third prototype vehicle under this project is expected to be completed in the middle of 1981. A project for the construction of 10 prototype vehicles in the 1 ton class has also been taken up.

BIO-ENERGY

In the area of bio-energy special emphasis is being given on energy plantations, bio conversion processes and biogas technology. A special feature of 1980 - 81 was the initiation of a number of demonstration cum-experimental types of programmes. An integrated approach for the production and utilization of biomass and utilization of the existing expertise in the country, is being given high priority. Expert panels on bio-energy have met several times, prepared status reports and have identified priority areas of research in which projects have been initiated.

Production and Availability of Biomass: During this year, the Expert Group on Production and Availability of Biomass held two meetings on 11th March and

18th June, 1980 and discussed two major issues:

(1) Establishment of Biomass Research Centres; and

(2) A Status Report on the Production and Availability of Biomass.

The proposals on the establishment of Biomass Research Centres at Madurai Kamraj University, Madurai and NBRI, Lucknow have been approved; work has been initiated at both the Centres. The main objectives of these research centres are:

- To assess the potentials of plant species of proven adaptability to soil alkalinity for biomass production.
- To standardise agro-techniques.
- To study photo synthesis in relation to plant productivity and nutrient cycling of selected species and nitrogen economy.
- To survey the land and water potential of the area and formulate programmes on the utilization of municipal and agricultural wastes for energy conversions.
- To concentrate on energy crops of terrestrial and aquatic nature.
- To undertake feasibility studies on more efficient uses of the biomass for obtaining maximum energy and to develop appropriate technology for energy crops, production systems, harvesting and collecting, pre-treatment and conversion.

An outlay of Rs.25 lakhs for a period of three years has been earmarked for these two projects. Based on the results obtained at these two centres, other similar centres will be started at appropriate locations.

A status report on production and availability of biomass has been printed and the same was presented at the 68th Session of the Indian Science Congress at Varanasi. The report has highlighted the work done on biomass from microbes, energy plantations, utilisation of marginal soils for energy

plantations, agro-forestry and social forestry practices, biomass centres in the country and utilisation of agricultural and agro-industrial residues. After in-depth discussions of the Expert Group, and after incorporating various suggestions received from eminent scientists and technologists working in this area, the future perspective and prospects of improving the biomass technology, and recommendations for future research work have been given in the status report. The report is being circulated to concerned university departments and national laboratories to receive project proposals in priority areas of research for biomass production.

Conversion and Utilization of Biomass: The Expert Group on Conversion and Utilization of Biomass in its 3rd meeting held on 29th November 1980 has discussed in detail the recommendations of the International Course cum Symposium on Bioconversion and Biochemical Engineering held at IIT, New Delhi. The recommendations discussed related to bio-technology training programmes; fuels and feedstocks from biomass and biotechnology for rural development. A note is being prepared on the subject for introduction of biotechnology as a subject for higher education, for the consideration of the UGC and the Ministry of Education. A coordinated programme is under formulation on the bioconversion of straw and ligno-cellulosic materials to alcohol. IIT New Delhi, NDRI. Karnal, IVRI, Izatnagar, NCL. Pune and GB Pant Agricultural University Pantnagar will collaborate in this project. The results obtained under the project on conversion of cellulosic residues to alcohol will form the basis of these coordinated projects.

A proposal to establish an integrated pilot plant to test a variety of bioconversion processes already developed in the country was also discussed in the meeting and a detailed proposal on the subject is being prepared. The modernisation and improvement of the existing processes for the production of alcohol, and the engineering aspects of fermentation technology, were also discussed by this Committee and a detailed note on the subject is under preparation. A directory of experts working in the area of bioconversion is also being perpared. A revised status report on the subject which will give recommendations for future thrust areas of research is being finalised.

Research proposals on energy plantations and conversion of agricultural waste into energy rich materials are being processed in the Department.

The problem of spread of water hyacinth in the lakes of Udaipur City was brought to the notice of the Prime Minister; and DST examined the possibilities of eradication of the weed from the lakes as well as its utilization. The department consulted experts in this regard and a team of DST officials and experts visited Udaipur and discussed the matter with the State Government officials. On this basis an integrated programme was prepared and suggested which includes:

- Mechanical removal of the weed;
- Directing the sewage and effluents away from the lakes;
- A mass educational programme for the public;
- Treatment of the lakes with weedicides and ammonia to ensure no further growth of the weed;
- A constant vigil around the lakes;
- All precautions to be taken to ensure the cleanliness of the water used for drinking purpose and from the public health point of view etc.

A similar programme has also been prepared for the lakes at Jaipur.

The weed has also spread in the water bodies near the Ghana Bird Sanctuary in Bharatpur. It is proposed to set up a biogas plant in the premises of the Guest House of the Bird Sanctuary which will use water hyacinth for production of biogas. Detailed drawings for the plant have been prepared and preliminary exploration of the site has been done.

General progress has also been made on the methods of utilising water hyacinth through biogas generation, conversion to manure, paper etc.

BIOGAS TECHNOLOGY

Under the second phase of the All India Coordinated Project on Biogas, a national technical committee on biogas has been set up. Work has been accelerated on the improvement of designs, use of diverse feed material, development of anticorrosive paints, generation of gas at low temperatures, use of local material for the construction of biogas plants, a pre-installation socioeconomic survey and distribution system of gas for cooking and lighting purposes and for generation of motive power. A new construction material for the digestor made up of lime known as 'Lympo' has been developed and is now being used. Through this use, the cement consumption can be brought down by 20 to 30% thus bringing down the cost of construction by about 20%. In respect of the drum/gas holder, ferro-cement has been developed as construction material. A new anti-corrosive paint has been developed and is being tested in different types of plants.

Three meetings of the Technical Committee on Biogas were held during this year. Various R&D aspects such as use of diverse feed materials, generation of gas in winter months, reduction in the cost of the plant, use of locally available construction material, measures for popularisation of biogas technology in the country and new proposals on biogas were considered by the committee.

As a continuing activity from the first phase of the All India Coordinated Project, to complete work on various aspects, the National Sugar Institute has worked on the digestion of bagasse; at the IARI, New Delhi work on the production of gas under varying climatic conditions as well as digestion of different types of agricultural wastes has been done. At MACS, Pune, studies on the isolation and identification of micro organisms for the production of biogas, on the identification of non-cellulosic and anaerobic/organisms from the fermenting slurry, on the production of biogas at elevated temperatures and on the effects of additives on the production of biogas were conducted. Work on the production of gas from mixed dungs, and agronomic field experiments to evaluate the manurial value of the effluent slurry of gobar gas plant, have yielded important results.

A project financed by DST on the conversion of banana waste into biogas is being implemented at Vishwakarma Mahavidyalaya, Gujarat.

An important activity in the area of biogas this year has been initiation of 21 community type biogas plants as demonstration-cum-experimental units in different parts of the country. In order to demonstrate the use of biogas produced from community type biogas plants under varying agro-climatic conditions, projects in collaboration with KVIC, PRAD, NCAER and IIM, Ahmedabad have been launched.

The community-type biogas plants are being set up in different locations as given below:

1. Andhra (Veeranjaniyapuram, Dist. Krishna).
2. Andhra (Karimnagar, Dist. Medak)
3. Karnataka (Barkur, Tq. Udupi, Dist. South Kanara).
4. Tamil Nadu (Gandhigram, Village-Kaunthigoundanpatti, Dist. Madurai).
5. M.P. (Village Shapura, Dist. Bhopal).
6. Rajasthan (Village Devgarh, Dist. Udaipur).
7. Maharashtra (Village Dhaniv, Dist. Thana).
8. Maharashtra (Village Walhe, Dist. Pune).
9. Haryana (Agricultural University, Hissar)
10. New Delhi (Village Masudpur).
11. W.Bengal (Hooghli Dist.).
12. Kerala (site to be decided).
13. U.P. (Gujaria, Dist. Lucknow).
14. U.P. (Kashipur, Dist. Nainital).
15. U.P. (Jainpur, Dist. Bulandshahr).
16. U.P. (Pantnagar, Dist. Nainital).
17. U.P. (Doiwala, Dist. Dehradun).
18. Bihar (Patna).
19. Himachal Pradesh (Jangaria, Dist. Kangra).
20. Gujarat (Gujarat Agricultural University, Anand).
21. Punjab (Punjab Agricultural University, Ludhiana).

Close interaction is being ensured in implementing the biogas programme with other concerned Ministries such as those dealing with Agriculture, Rural reconstruction and Energy.

A status report on Biogas Technology in India has been published. A Committee appointed by Secretary, DST, to examine and evaluate various existing designs of biogas plants being currently used in India has also submitted its final report to DST.

Constitution of two Task-forces, one on microbiology and the other on engineering aspects is also being taken up. Two issues of biogas news-letter have been published.

MHD PROGRAMME

Work has continued on the project for setting up an Experimental MHD Power Plant of 5 MW (Thermal input capacity) based on coal at Tiruchirapalli. This project, which is being jointly implemented by BARC and BHEL is expected to be completed by 1982. The MHD channel has been fabricated and tested in the UO 2 facility in USSR. Civil construction work relating to the plant has been proceeding satisfactorily. A large portion of the equipment and machinery has been received and installed. Further equipment and instrumentation as well as material for the magnet are being procured. The project is proposed to be extended up to 15 MW level by about the end of the Sixth Plan. The revised outlay for this project for the year 1980-81 is Rs.25 crores. It is expected that the outlay of this project during the Sixth Plan will be Rs.10 crores.

OTHER R&D PROGRAMME IN ENERGY

The Department continued to support the development of a cold storage unit based on geothermal energy at Manikaran (H.P.) by IIT, Delhi and Geological Survey of India. Projects on thermal energy storage system have also participated in the activities pertaining to R&D in the fuel and power sector of other organisations. New emphasis is being developed in relation to

activities connected with energy conservation. Studies relating to fuel economy in the agricultural and transportation sectors are being initiated.

The Department has been actively involved in the preparation for the UN Conference of New and Renewable Sources of Energy to be held in August 1981 in Nairobi. The Department is represented on the Inter-Ministerial Committee for this Conference and also participated in the meeting of the Inter-Governmental Preparatory Committee held in Geneva in July 1980.

Reported In the 1980-81 Annual Report of the Department of Sciene and Technology, Technology Bhawan, New Mehrauli Road, New Delhi 110 029.

MINISTRY OF AGRICULTURE
Department of Agriculture and Cooperation
New Delhi

It is estimated that about 980 million tonnes fresh weight of cattle dung is produced in the country annually. Even if one-third of the total cattle dung is assumed as available for biogas plants, there is a scope for setting up 10 million family size plants. The potential could be enlarged by using agricultural residues and water-plants in addition to cattle dung, provided suitable technologies for the purpose are developed.

Fifth Plan

In the wake of developing energy crisis, Ministry of Agriculture initiated a Central Sector Scheme on Development of Local Manurial Resources of which biogas was a component. Between 1974-75 and 1978-79, over 70,000 plants were completed under the Ministry's programme against a target of 100,000 plants. As an incentive to beneficiaries, central subsidy amountng Rs.6.85 crores was released. The pattern of Central subsidy was 20% for all farmers, 25% for small and marginal farmers for small size 2 and 3 cum plants, 33% for community plants, 50% for hilly and tribal areas and 100% for fixed dome demonstration plants and night-soil biogas plants on pilot basis.

The programme was implemented by a number of agencies particularly Department of Agriculture in Haryana, Madhya Pradesh, Punjab and Uttar Pradesh, Department of Rural Development and Cooperation in Karnataka, Department of Rural Development and Local Administration in Tamil Nadu, Khadi and Village Industries Commission (KVIC) and a number of State Agro-Industries Corporations and Khadi and Village Industries Boards. Commercial and Cooperative banks supported the programme by providing loans for setting up a biogas plants. The Reserve Bank of India instructed all Cooperative and Land Development Banks to provide medium terms loans for such plants under "Approved Agricultural Purposes". The Agricultural Refinancing and Development Corporation agreed to provide refinancing

facilities to all eligible banks for financing of biogas plants under Agricultural Priority Sector Scheme.

Emphasis was also laid on setting up community biogas plants. In all, out of four proposals for community plants approved, two were set up during 1978-79 at village Kodumunja in district Karimnagar of A.P. and Sri R.K. Mission Sevashram, Kankhal in district Saharanpur of U.P., with subsidy from the Ministry of Agriculture. A third plant at Fateh-Singh-Ka-Purwa in district Etawah of U.P. was set up during 1978-79 by the Planing Research and Action Division, Lucknow with financing from UNICEF.

An attempt was also made to select some institutions using dry conservancy system, for sanitary disposal of night soil through biogas plant on the basis of technology developed by National Environmental Engineering Research Institute, Nagpur. In all, out of 7 institutions selected, each of five institutions - one each in Rajasthan, Tamil Nadu and Goa, and two in Uttar Pradesh, was given first instalment of central subsidy amounting Rs.20,000/- for setting up of a night soil biogas plant. It was envisaged that central assistance on the capital cost for each plant would be limited to a maximum of Rs.50,000/- excluding the cost of construction of latrines. So far, work for installation of such plants has not started due to certain technical snags and administrative reasons.

In April 1979, the Central Sector Scheme was transferred to the State Sector. Efforts were made to persuade State Governments to continue the implemenation of the programme with provision of subsidy as was followed under Central Sector during 1978-79. In all Union Terrorities, the programme was, however, continued under Central Sector Scheme. Some of the State Governments, particularly Uttar Pradesh and Karnataka provided funds for implementation of the programme.

Over 85,000 biogas plants have been set up by 1979-80, in different States/Union Territories as indicated in the following page:

State	No. of biogas units set up during 1974-75 to 1979-80.
Uttar Pradesh	20,225
Haryana	10,272
Bihar	9,526
Maharashtra	9,227
Gujarat	8,237
Karnataka	6,942
Tamilnadu	5,999
Punjab	5,575
Madhya Pradesh	3,442
West Bengal	2,352
Andhra Pradesh	2,282
Kerala	1,317
Orissa	553
Rajasthan	355
Assam	78
Delhi	50
Others	360
Total	85,783

In addition, about 8,000 to 10,000 biogas units are expected to have been installed during 1980-81.

The most glaring shortcoming of the Fifth Plan programme was that it confined itself merely to providing subsidies to the beneficiaries through either State Government or the KVIC. For a programme to make a fast and steady progress covering all potential villages in a phased manner, it is indispensable to make adequate provision for:

- technical backstopping,
- training & extension,
- infrastructure support including maintenance service
- adequate subsides and
- institutional finance.

New Cheaper model of biogas plant

Besides lack of proper organisational and extension support, high cost of the biogas plants was identified as the important constraint towards faster promotion of the programme. At the instance of Ministry of Agriculture, already a cheaper fixed dome model has been developed by Planning Research and Action Division of State Planning Research and Action Division of State Planning Institute, Uttar Pradesh. It dispenses with the use of steel gas holder which is a must in conventional biogas plants. It is a brick-masonary structure which costs 30% less than the cost of same capacity of conventional model. In February 1979, the new model was approved by Government of India for propogation. In Uttar Pradesh already 4,000 such units have been set up. Development of fixed dome biogas plant has opened a new line of work to further bringing down cost.

In order to create a cadre of trained maskns, which is a must for setting up fixed dome model, the State Government of Uttar Prdesh has also developed a training programme. At the request of Ministry of Agriculture, a non-governmental organisation, Action for Food Production (AFPRO) has taken active interest in its promotion and till now has established cheaper fixed dome model for demonstration and training purpose in a number of States/Union Territories. The AFPRO has constituted 3 teams, each consisting of one master mason and one assistant mason for deputing on demand to different voluntary organisations for providing technical guidance and actual installation of fixed dome plant. A 'Kalinga' model developed recently by Department of Agriculture, Govt. of Orissa is also considered to be a promising model in future.

Sixth Plan

It has been decided that the Central Government should play a much bigger role in promotion of biogas in the country. A National Project on Biogas

Development is proposed to be taken up during the Sixth Plan period starting from 1981-82. The Planning Commission has provided an outlay of Rs.50 crores for the purpose. A target of 400,000 family size biogas plants has been proposed for the Sixth Plan. The details of the project are being worked out. It may envisage appropriate subsidies, arrangements for technical back stopping, arrangements for training and extension, strengthening of organisational infrastructure, provision for turn-key jobs and facilitation of institutional finances.

Infrastructure Support

As this programme is inherently decentralised in nature involving a large number of small civil works in the rural areas, it is not possible in a vast country like India for one single agency to execute the programme throughout the country. Therefore, multi-agency approach is imperative involving the KVIC, State Governments, Khadi & Village Industries Boards, State Corporation like Agro-Industries and Dairy Development Corporation and also recognised non-official organisations of demonstrated excellence and competence. In the past, programmes were undertaken in too scattered a manner to make an impact. Therefore, an area of cluster approach would be essential for ease of management, supervision and post installation care. Also, it has been felt that biogas programme should be coordinated with related programmes like Cattle-cum-Dairy Development Projects. The need is being recognised of integrating the biogas programme with the activities of Operation Flood which aims at covering 10 million families and rearing a national herd of 15 million cattle of improved variety, most of which are stall-fed. Operation Flood can provide crucial support to the programme through its cooperative infrastructure and excellent facilities of extension, training, logistic and mass communication.

Community Biogas System

Together with family size plants owned by one or more family(ies) promotion of community biogas plants is also essential. These plants have advantages of their own in terms of: economy of scale; extension of benefits to those who either do not have the minimum number of cattle or lack

entrepreneurial ability; diversification of the uses (conversion into electricity and motive power for irrigation, village lighting and water supply, operation of small farm machines and small tractors, establishment of biogas-algal-fish cultures). A beginning has already been made in this direction. It has been arranged to set up a community biogas plant of 140 cms capacity at village Khoraj, near Ahmedabad in Gujarat with the UNICEF assistance. Further the UNICEF has agreed to assist another 15 plants during 1981-83.

It is realised that systems approach to biogas development will help in its large scale promotion. While solutions should be found out for operational problems like use of different organic materials as feed-stocks, portability of biogas, simple devices for removal of water condensate from pipeline, corrosion of gas holders, leakage of fixed dome plants, reduced gas production in winter months, etc., all out efforts are needed to transfer the available technology to rural areas. Each region or State should develop its management system to promote this technology under the coordination, supervision and guidance of an apex body at the Centre.

Communicated by: Dr. K.C. Khandelwal, Specialist (Organic Fertilizers), Ministry of Agriculture, Department of Agriculture & Cooperation, New Delhi).

ANNA UNIVERSITY OF TECHNOLOGY

Madras

Some of the areas in where work is being initiated at the Anna University of Technology, are listed below:

1. Use of ethanol as a substitute fuel in I.C. Engines.
2. Installation of solar stills, solar driers and solar refrigeration systems.
3. Installation of community biogas plants using organic, animal and human wastes.
4. Improved design of animal powered vehicles.
5. Mathematical modelling of energy systems.

Ethanol as a Fuel

The Department of Heat Power Engineering, College of Engineering, Guindy, of this University is engaged in research and developmental activities from 1973 onwards, in the use of ethanol as a substitute fuel in engines. Experimental programmes have been initiated for the use of ethanol as a clean fuel in single cylinder and multi-cylinder automotive spark ignition engines. After successful laboratory tests, vehicles fitted with 1389 CC engine are operating for the past two years. Data have been collected on the long term effects of the use of ethanol in these types of engines. A 2500 KM road test involving two vehicles fitted with 1489 CC spark ignition engine was conducted successfully in July 1980. Further laboratory and road tests are in progress. Use of ethanol as a dual fuel in compression ignition engines have also been undertaken and tests have been conducted both in single and multi-cylinder compression ignition engines. A six cylinder automotive compression ignition engine fitted to a commercial vehicle was tested with ethanol as a dual fuel and it has been possible to replace diesel by 40% by making suitable modifications in the fuel intake system. Further tests for optimising the design modifications are under progress. The use of ethanol of a clean fuel in conjunction with vegetable oils as lubricants have been tried to two-stroke cycle spark ignition engines (used in two wheelers). The project on the

utilisation of ethanol is supported by a grant from the Government of Tamil Nadu.

Solar Stills

The Centre of Environmental Studies at the University has constructed a large scale solar still at a village 30 km away from Madras with a view to provide the villagers with clean drinking water. This plant is of modular type with 16 stills covering a total area of 270 sq. m. Brackish water from a neighbouring well is pumped into an overhead tank and by gravity flow the water is led into the still. The output of the still ranges from 500 to 800 litres per day depending upon the season.

Solar Drying

In a predominantly agricultural society, paddy drying during monsoon season is an important harvest activity. To facilitate this operation, the Mechanical Engineering Division of the University has designed and erected a solar heated dehumidifier system. In this set up, air which is dried by passing through a chemical dehumidifier is used to remove moisture in the paddy. The chemical dehumidifier is regenerated by heating it. The heat for this operation is from a array of solar flat plate collectors.

Solar Ice Machines

Investigations have been initiated for the design and fabrication of a mini solar ice plant which is basically an intermittent vapour absorption system using ammonia-sodium-thiocynate as refrigerant absorbent combination.

Biogas Plants

A biogas demonstration gas plant using kitchen refuse and garbage have been put up in the college hostel and is being evaluated for its performance. This unit utilises 50 kg of refuse per day to produce 3 m^3 of gas which is utilised in the hostel kitchen. It is proposed to put up another plant in one of

the collage hostels where the discharge from the toilets will be utilised for producing biogas. A community biogas plant has been planned with a total capacity of 205 cum to cater to a group of 36 families in a tiny hamlet 30 km from Madras.

Bullock Carts

The Mechanical Engineering Department is working on a project for improving the bullock carts using scientitfic techniques. The improvements so far reported relate to replacing the bearings, reduction of weight and introduction of a brake system. Further modifications are being tried with different configurations of wheels and wheel components.

Energy Modelling

A research group is also engaged in the development of a mathematical model for the Indian Energy System to aid policy planners in energy forecasting and technology assessment. The group proposes to link the technological model with the economic model to study the pricing structure. The group would also study the effect of preferred scenarios; it is believed the results of these studies will throw more light on the future energy options. This project is funded by the Department of Science and Technology, Govt. of India.

Rural Energy Centre

Another project on which the University researchers propose to work relates to the setting up of a rural energy centre. The centre which is to be set up in a village envisages the simultaneous utilisation of different forms of renewable energy sources. The main aim of this study is to bring about a proper match between energy resources available in the village and its energy needs.

Communicated by: Dr. T.R. Jagadeesan, Prof. of Heat Power Engg., College of Engineering, Guindy, Madras 600 025.

ANNAMALAI UNIVERSITY
Department of Mechanical Engineering
Annamalainagar

Research work in solar energy utilization was started in 1966 by the Mechanical Engineering Department. Solar energy gadgets like solar focussing collector, solar water heater, solar air heater, solar still, solar cabinet dryer, solar airconditioner, solar milk heater, solar wax melter and one ton per day solar paddy dryer have been designed, fabricated and tested successfully.

Solar Paddy Dryer

The Department of Science and Technology, Government of India sponsored a project at this university for the development of a solar paddy dryer having one ton per day capacity. The work on this project was started in January 1975 and completed by January 1978. The construction of the solar paddy dryer is of roof cum collector type. The flat plate solar collector forms the roof of the building in which drying bin is put up and also additional space is available for storing or other purposes. This roof cum collector design of approximately 50.75 m^2 for air heating is the first of its kind in India. The one ton per day capacity plant was successfully completed and the outcome of this research work aided the construction of a commercial plant of 10 ton per day capacity at Central State Seed Farm at Ludhiana, Punjab.

Solar Air Heater

A research project on conversion of existing roof into a solar air heater sponsored by the Department of Science and Technology is under progress. A pilot plant roof of size 3.6 x 2.1 m was fabricated and converted into a solar air heater. The results of this study leads to the establishment of design details for a large scale industrial roof solar air heaters by converting the existing roof.

Laboratory Facilities

The laboratory is equipped with the following facilities:

1. A bimetallic pyranograph for recording total solar radiation.
2. A cup type anemometer to measure the wind velocity
3. A hot wire anemometer to measure the velocity of air in ducts.
4. A thermohygrograph to record the daily temperature and humidity of atmospheric condition.
5. Digital millivoltmeters and strip chart recorders to measure temperatures.

Future Programme

A collaborative work with the Colorado State University, U.S.A., under Indo-US Collaborative research for the development of optimisation of solar drying system for agricultural produce is envisaged.

Latest Publication

1. Industrial Solar Air Heaters by V.R. Muthuveerappan and others. Proceedings of the National Solar Energy Convention 1980, Annamalai University 19-21, Dec 1980; 96-101.

Communicated by: Prof. V.R. Muthuveerappan, Annamali University, Annamalainagar 608 101.

BENGAL ENGINEERING COLLEGE
Howrah

Research and Development in solar energy, MHD, Biomass and Wind power started in the year 1976. Emphasis is laid in the development of experimental models for the renewable sources of energy for commercial exploitation and that product development be based on proper design criteria satisfying functional requirements under indigenous conditions, keeping in view the social and economic constraints that operate. Thus, theoretical research work has been taken up in order to gain an insight into the systems designing. A summary of work is reported here.

Solar Energy

Flat plate collectors of various configurations using water as transport media in the temperature range of 120° C are being studied by the Department of Mechanical Engineering as well as of the Department of Post-graduate Training in the followig areas:

1. Heat transfer characteristic of a flat plate collector.
2. Heat losses and pressure drop through a collector.
3. Energy balance for a flat plate collector.
4. Optimisation of collector design.
5. Optimising the design parameters of the collector and the cost thereof.

The interaction of solar system components in response to the climate and energy demands determines the useful energy delivery of the system. The solar energy group is, therefore, engaged in the analytical studies of the various parameters involving system analysis and its components and the economic implication of the solar system.

Several industries in India have shown interests to develop solar driven refrigeration and air conditioning system for space cooling with a view to

conserve electricity. Researchers have already started working in this line, in collaboration with a refrigerating industry in Calcutta. An analytical design study has been made and the economic evaluation of such system has been worked out. Due to high operating cost, commercial application of such system is not feasible. Presently, the process of redesigning the system with the help of computer has been effected.

The graduate and doctoral students are working on the theoretical aspects of design and optimisation of solar thermal electric power plant. The primary object of this study is to develop a suitable design of solar electric power plant for undertaking a pilot plant project which would, in turn, give an insight to understand the complex engineering designs of the various component associated with the project and to evaluate economic viability of conceiving a full-fledged design of a commercial solar electric power plant.

MHD Power Generation

Since 1978, a couple of doctoral students have been working in the design and optimisation of MHD system for generation of electric power. At the inception of the project researchers faced insurmountable problems with regard to choosing of appropriate parameters for their analytical studies as it is quite well known that many practical problems with MHD power systems remain to be solved, others to be discovered. The best way to couple MHD with conventional power systems is still a subject of study. It is not possible to extract all the energy from the hot gases using MHD. As energy is extracted, the gas is cooled, and this reduces their ability to conduct electricity. So rather than throw away the energy in the moderately hot exhaust from MHD generator, one can use this energy to boil steam for a conventional steam power plant. The MHD unit then becomes a "topping cycle".

Computer simulation indicated that cooling the electrodes might solve the problem of melting temporarily. But if the gas close to the electrodes gets too cold, it can no longer be ionized and hence it will not conduct the desired current. Potential differences also tend to develop along the channel in the

flow direction, and this gives rise to currents flowing parallel with the flow. And therefore segmental electrodes system seemed to be the solution. But this gives rise to other complex problems which need be solved. One of the major problems encountered here is that the magnets used large amount of power, usually more than the channel itself puts out. It is expected that the problem of high magnet power will be solved through use of superconducting magnets.

Wind Power

The Applied Mechanics Department of the College took up wind power project in collaboration with the West Bengal State Electricity Board, Calcutta, way back in the year of 1976. The work commenced towards the latter half of 1976 in the fabrication of windmill. After careful examination of the promising areas of utilisation of wind energy, in the State of West Bengal, the following areas of work have been identified :

1. Study of windmills for water pumping and generation of electricity.
2. Exploring possibility of utilising windmills for irrigation purposes.
3. R&D projects having long term potential application of windmills for energy storage system as well as to optimise the appropriate design of windmill for rural applications.

Educational Programme

Several courses based on the energy conversion technology and energy studies have been introduced in the undergraduate and post graduate levels. Since July 1976, a principal paper on energy conversion technology has been introduced in the two year M.E. course in the Department of Mechanical Engineering. The course work includes general aspects of energy resources, energy economy, environment and basic concepts related to renewable sources of energy as the foundation to the specialised courses in different areas. Sponsored candidates from industires are given preferences in admission. In addition to the above, there is provision for Ph.D. work on energy system study. Efforts are now being made to organise the project work of undergraduate and post graduate students in collaboration with industry both in private and public sectors.

Future Programmes

Most of the ongoing projects will continue. Also, it is expected to take up theoretical design and optimisation study on geothermal sources of generating electric power. Fusion-fission hybrid system analytical work is already in progress since 1979 in collaboration with Stanford University, U.S.A. and Fusion Energy Foundation of America.

Communicated by : Prof.Dr. Sanat Biswas, Prof.of Nuclear Engg. & Energy Conversion Technology and Head of the Dept. of Post Graduate Training, Bengal Engineering College, University of Calcutta, Howrah 711.103.

CENTRE OF POSTGRADUATE INSTRUCTION AND RESEARCH

Microbiology Department

Goa

An on-going project with the centre is on ecology and the role of green sulphur photosynthetic bacteria to combat pollution and enhance bioproductivity.

The bacteria has been isolated from estuarine sediments of the various estuaries in Goa. The sediment was collected from about 30 cm deep and was inoculated into McCartney bottles containing Larsen's medium. They grow slowly and good growth appears after about two weeks. They were purified by the roll tube method and identified according to Bergey's manual. It was found that the chlorobium species dominated. The growth of the isolates was measured in synthetic media, tested for nutritional contents in terms of protein carbohydrate and nitrogen over a period of 18 days. The proteins were tested according to Lowry's method, carbohydrates by Anthrone method according to kjeldahl-Nesslerissation by King. Growth studies showed that with increased growth, the protein, carbohydrate and nitrogen contents also increased. Maxmium growth appeared on the 10th to 12th day.

Green sulphur Photosynthetic bacteria were used in the anaerobic digestion of sewage as they are able to convert H_2S to sulphate which is totally devoid of this odour, by using H_2S as an electron donor. Besides rendering sewage non-toxic, the treated effluent can be used in agriculture as certain species of these bacteria are known to fix molecular nitrogen. Once the sewage is treated, the toxic products lessen and after dilution with natural waters makes it better suited for growth of vertebrates and invertebrates increasing bioproducivity and thus helping in equilibrating the marine good cycle.

These photosynthetic bacteria being anaerobic use up the waste content present in sewage without a demand on dissolved oxygen, thus purifying sewage with a simultaneous metabolism of organic substrates.

The pigment and bacterio-chlorophyll studies were also carried.

Due to the high caloric content of the cell mass, it is used as fish food for growth of fresh water fishes. Bacteria after 12 days growth with maximum O.D. is centrifuged for 15 mins., at 3750 rpm and the supernatant is discarded. The pellet is dried in an oven. A 10% mixture of this cell mass and fish food are given daily to the fishes (8% of the body wt. of the fishes). The fishes with Photosynthetic bacterial feed grow much faster in weight and length compared to the control.

Publications

1. Use of green sulphur photosynthetic bacteria to combat pollution and enhance bioproducivity National Solar Energy Convention, at Annamalai University, 19-21 Dec, 1980.

2. Control of pollution by green sulphur photosynthetic bacteria. National Symposium on Applications of Nuclear and Allied Techniques in Public Health and Pollution Control, Bhabha Atomic Research Centre, Bombay 12-13 Feb, 1981.

Communicated by: Ms. Vera de Souza, Microbiology Dept., Centre of Post Graduate Instruction and Research, Panaji, Goa.

COIMBATORE INSTITUTE OF TECHNOLOGY

Coimbatore

Work on utilisation of renewable resource of energy was initiated in 1975. A "Solar Still" was developed for supplying the distilled water to institute laboratories. Continued interest in this field has led to the fabrications of a small windmill, solar collectors, water heaters, biomass plants etc.

The double sloped solar still is capable of producing 10 litres of distilled water/day during winter at Coimbatore. It was made out of GI sheets with blackened surfaces. Evaporated water condensed on the glass roof top, trickles down to the trough. The entire unit was fabricated with inexpensive materials and skills available within the institute laboratories. Presently work is going on in improving the system. Also, efforts are underway to improve upon the efficiency of the collector by using different absorbing surfaces and minimising the heat losses.

A paraboloid type concentrating collector with a concentration ratio of around 400 and the outer diameter of 1 m was fabricated. The main skeleton structure was made out of steel rods and strips with glass mirrors embedded in it. Later on the glass plates were replaced with highly polished aluminium plates, for better concentration effects as it follows the paraboloid profile better. Also two types of tracking systems, one using gravity method and the other employing 4 LDRs to control the motor (which in turn tracks the sun at five minutes intervals) have been designed and fabricated.

A windmill with Savonius rotor has been designed and fabricated for pumping water. The sails were made of jute and tarpaulin with an overall size of 2 m base and 2.5 height. It was erected over the institute's hostel. Further work on improving the structural rigidity of the system is underway.

Flat plate solar collector of roll bond design has been fabricated for higher utilisation of exposed area. An optimal absorbing surface has been produced by the use of selective coatings. Thermostatically controlled valve has been used to by-pass the hot water to insulated storage tank. Collector design is being modified to facilitate a simple construction of the roll bond collector.

Communicated by: Dr. R.V. Srinivasan, Prof & Head of the Dept. of Mechanical Engineering, Coimbatore Institute of Technology, Coimbatore 641 014.

GOVERNMENT COLLEGE OF ENGINEERING AND TECHNOLOGY

RAIPUR

Research and development work in the field of solar and wind energy is conducted by the Department of Mechanical Engineering. The major achievements include the development of flat plate collectors, solar spheroidal reflectors, cylinderical paraboloidal solar water heater, solar energy storage system using rock piles, solar stills and water lens. These projects are briefly described below :

Continuous Solar Grain Drier

Continuous grain drying system has been successfully designed and fabricated. The effect of mass velocity inlet condition of air/void ratio of the product bed profile on the drying process is being investigated. It is aimed to optimise the system for minimum pressure drop during the forced convective mass transfer in the drying process.

A solar fruit and vegetable drier was fabricated during 1980. Air preheated in a solar air heater located at the base of the drier, is admitted at the bottom of the drying enclosure. From there it rises through the drying racks, dehydrating the product laid on them and is then exhausted through an opening located at the top of rear wall of the chamber by natural convection. Drying is also carried out with the help of direct sunlight reaching the product through the transparent side front and top panels.

Effect of Byoyancy on Heat Transfer Rate in Solar Air Heater

To study the influence of inclination on mixed convection heat transfer for laminar flow through an annulus, a test section has been fabricated.

Solar Energy Refrigerator

An ammonia water intermittent solar refrigerator has been designed and fabricated for making ice. The solar refrigerator consists of a tubular flat plate collector, which serves as the generator. Solar radiation striking the generator raises the temperature and pressure of the mixtures. Generation of ammonia continues at constant pressure as solar heating is continued. The generated vapours pass through an air cooled rectifier and get condensed.

Design of Wind Turbine: A Graphical Approach

A simple graphical procedure for designing a wind turbine of high cup speed ratio has been developed, which is to be fabricated with inexpensive materials like wood for blades. The advantage of this procedure for design is that it is very simple and windmill of any capacity can be designed quickly.

Laboratory Facilities

A solar energy laboratory consisting of basic solar energy devices exist for imparting instruction to the students. Facilities for testing devices such as air heaters, water heaters, solar cookers, solar stills, etc., are being set up.

Educational and Consultancy Services

The teaching and training programme consists of imparting prefinal mechanical engineering students with an elementary course in collection and utilisation of solar energy and engaging the final year students in their project works in the same field.

Consultancy services are available in the field of solar energy by the expert faculty members of the Institute who have gathered good experience in guiding the research and development projects. Several technical and research papers have also been contributed at various international and national conferences/seminars in the field of solar energy.

Communicated by : Dr. M.L. Verma, Lecturer in Mech. Engg., Govt. College of Engineering & Technology, Raipur 492 002.

GOVERNMENT ENGINEERING COLLEGE

Jabalpur

Work on utilisation of solar energy was initiated at GEC through projects undertaken by the students under guidance by the staff of the college. Till March 1981, small solar devices, suitable for domestic use, such as portable solar wax melter, solar water heater-cum-storage system, solar water heater (tube type), parabolic spheroidal concentrator (sun basket) for cooking, box type cooker with twin reflectors, solar still, solar cabinet drier, hydraulic auto sun tracking system, forced convective solar air heater, etc. have been fabricated and tested.

Portable Solar Wax Heater

The equipment is kept in open ground to absorb solar energy. By adjusting the lever, attached to revolving cum tracking stand, the hot box is turned left or right so that the absorber plate faces the sun. Then by adjusting the screw of slotted clamp, the hot box is turned up or down so that sun rays fall perpendicular to the absorber plate. In this position all the sun rays falling on four glass mirror reflectors are reflected on absorber plate. After few minutes the lid is lifted up, raw paraffin wax pieces are spread over the carrier plate, the lid is again kept in the original position. This way the wax is sandwiched between hot plate and wax carrier plate. The heat collected by absorber plate heats and melts the wax. Melted wax collected in channel is taken out through a pipe and is poured into moulds. After sufficient cooling of moulds the candles are taken out and are stored for use. Melted wax can also be used for coating of bread, butter and other wrappers. For melting of wax it takes 8 to 10 minutes in early and late hours of the day and 5 minutes during noon hours. Maximum temperature on absorber plate recorded was 180°C. Absorber plate area is 60 x 60 cm.

A modified version of the above mentioned solar device was fabricated. Main modifications which were implemented are: (i) use of 4 rectangular and 4 triangular aluminised film reflector instead of 4 plane mirror reflectors, (ii) provision of feeding of raw paraffin wax in the form of rectangular ingot 45 cm

wide and 2 cm thick instead of feeding in pieces. (This prevents the lifting of lid for pouring of wax), (iii) continuous feeding and melting of wax instead of intermittent feeding.

Solar Cooker

A parabolic spheroidal concentrator (sun basket) for cooking was fabricated and tested. It is observed that though parabolic concentractor reflects and concentrates more solar energy, they have few problems such as (i) at least 1.4 m diameter for concentrator is required for cooking, thus its handling is difficult, (ii) continuous sun tracking is necessary, (iii) loss of heat by radiation to atmosphere due to wind, from cooking vessel, since cooking vessel is kept in open, (iv) difficulty in making a perfect parabolic reflecting surface. These drawbacks restricted its use for domestic cooking.

Thus a suitable solar cooker, a box type with twin reflector was fabricated and tested. The box is kept in open in a position so that one reflector faces east and the other south. The double glassed lid is lifted up and four flat circular cooking vessels (of aluminimum) with a close fitting blackened top lid, containing rice, dal, vegetables, etc., with sufficient amount of water, are then placed on metalic tray and then lid is kept in closed position.

The sun's rays falling on glasses passes through the glasses and falls on metallic tray. The sun's rays falling on both the reflectors are reflected and enters the box through the glasses of the lid. The interior of box which is a blackened surface absorbs almost 95% of sun's rays incident on it. Air gap between the two glasses of lid prevents the heat from the top.

The tray gets heated up and in the process the cooking materials kept in the container starts boiling. The first meal when kept at 9 a.m. is ready by 12 noon and the second meal when kept at 1.00 p.m. is ready by 4 p.m. For cooking evening meals the cooker is turned by 90° clockwise so that one reflector faces west and the other south. The deposition of water bubbles underneath the lower glass is the sign of completion of cooking.

Forced Convective Solar Air Heater

In this system lathe turnigs have been used as heat absorbing media. Flow of air can be controlled by controlling the regulator of blower. The air obtained from this solar air heater is 75° to 95°C for flow rate of 5.4 to 4.8 m^3 or 7 to 6.2 kg per hour. This air heater is suitable for comfort heatng of the room (4 x 4 x 5 m) in winter or for drying agricultural products prior to storage.

Apart from the above described portable solar appliances, solar still, cylinderical parabolic concentrator for hot water, hydraulic auto-sun tracking system of conventional type with minor modifications have also been fabricated and tested.

Communicated by: Prof. R.C. Agrawal, Lecturer in Mech. Engg., Govt. Engineering College, Jabalpur 482 011.

GOVERNMENT ENGINEERING COLLEGE

Ujjain

Research, design and development work in the field of renewable energy is being conducted by the Department of Mechanical Engineering in the following areas:

Natural Convection Solar Drier

The removal of moisture requires only low temperature heating which can be readily supplied by solar radiation. The objective was to design an efficient drying system for agricultural products.

A novel type of solar drier was designed using hot air. This was of matrix type and made of several layers of M.S. wire nettng mesh and painted with black paint having an absorptivity of 0.9. The frontal area of collector was 1.86 m^2. One clear glass was provided at the top to eliminate convective heat losses.

Design & Fabrication of Horizontal Axis Windmill

Wind power is a significant source of energy in rural areas. The use of horizontal axis windmill is mainly for water pumping and is best suited for places having considerable wind velocity. A low cost windmill with 5' wooden shaft and 3 triangular sails (each side being 5') was designed and fabricated to develop 3 H.P. at wind velocity of 25 km/hr. The material used was locally available Babool wood. It is to enable village artisans to construct the mill incurrig low cost.

Design & Developmet of Cylindrical Parabolic Solar Concentrator

A cylindrical parabolic concentrator of length 80 cms and width 83 cms was designed and fabricated. The reflecting surface was made of tin foil. A water pipe was placed along the focal length. Maximum temperature rise of

66°C was obtained with stagnant water. A temperature rise of 23°C was observed with a flow rate of 3 litres/hr and with a flow rate of 3 litres/min, a rise of 1.5°C was recorded.

Design & Development of Equilibrium Air Distillation

This project was undertaken to predict the performance of different qualities of gasoline and blends of gasoline and other fuels. A set-up was designed and developed for finding EAD (Equilibrium Air Distillation) temperatures for 16:1 A/V ratio. The results of experiments conducted were used tc plot EAD distillation curves. These curves can be used for predicting performance of fuels in an engine.

Design & Fabrication of Heat Pipe

A heat pipe was designed and fabricated with a wrapped screen wick for transferring about 100 BTU/hr. of heat at 478°K. One half of the heat pipe was designed to work as evaporator and other half as condenser.

Design & Fabrication of Biogas plant

A portable biogas plant suitable to cater for the needs of the cooking gas of a common Indian family was designed and fabricated. The aim is to test the digester for cowdung, chicken manure, and fruits and grass chipplings.

Ongoing Projects

The follwing projects are currently being undertaken:

Investigating the performance of a horizontal axis windmill.
Design and development of a three blade vertical axis windmill.
Design and development of a solar still.
Investigation on the performance of a natural convection solar drier.
Design and development of a solar cooker.

Faculty Members

The following faculty members are working in the field of renewable energy resources in the Department of Mechanical Engineerng:

Dr. B.K. Sthapak	. . .	Professor and Head
Dr. D.D. Agarwal	. . .	Reader
Shri S.B.L. Beohar	. . .	Lecturer
Shri R.C. Jain	. . .	Lecturer
Shri I.S. Gujaral	. . .	Lecturer

Cummunicated by: Shri S.B.L. Beohar, Dept. of Mech. Engg., Govt. Engg. College, Ujjain (M.P.).

INDIAN INSTITUTE OF SCIENCE

Bangalore

The Institute has a strong programme in the renewable energy resources area. The various departments and ASTRA, (the project for Application of Science and Technology to Rural Areas) have put together a coherent programme. The work can be divided into 4 main areas:

- The utilisation of direct solar radiation for metallurgical uses, generation of power, hot water etc.
- Wind mills for rural water pumping
- Biogas plants
- Other areas of interest include energy conservation measures through various methods such as reduction of weight in transportation vehicles, investigation into low energy-intensive industrial processes, technology forecasting of energy systems to understand future energy needs and the means for satisfying them etc. Also, various on-going studies include investigation of rural energy and material needs and the options for satisfying them based on renewable energy and material resources, alternative patterns for industrialisation of India based on a need based strategy, consideration for, environmental safety and conservation of resources.

SOLAR RADIANT ENERGY UTILISATION

1. Solar Furnace: Air and steam upto several hundreds of degrees can be obtained for process heat applications. Various other applications as in plastics industries, thermosetting resins for core and mould preparations for foundries, etc. can also be envisaged. Three designs of solar furnaces were made of which the details are given below:

   (i) Table Model - plated copper sheet reflector (spun). It has an aperture of 400 mm with manual tracking facility.

   (ii) Pilot Model - Polished spun aluminium reflector, with a 600 mm aperture, manual tracking and with provision for melting metals.

(iii) Working Model - It has an aperture of 3000 mm and manual tracking, with provision for melting metals. The reflector is made up of cold worked aluminium sheet segments riveted to an antenna frame work. The reflecting surface is aluminized mylar sheets, pasted over the aluminium sheets.

Temperatures of 200°C, 500°C and 850°C have been reached for the table model, pilot model and working model respectively. The working model furnace is expected to melt aluminium after some problems is tracking and focussing are overcome.

A spum aluminium reflector of 4000 mm aperture from the Electronics Corporation of India has now been procured. This has a smoother finish, better curvature due to the method of manufacture, and hence greater efficiency. Automatic tracking facilities, heliostats to augment the solar radiation flux, etc. are also planned. Experiments to access the suitability of these furnaces for other metallurgical uses will be carried including the determination of thermophysical properties of materials at elevated temperatures.

2. Paraboloid Cylindrical Concentrators: These have been built at the CISL (Centai Instruments Services Laboratory); such concentrators are used for medium temperature applications upto about 250°C. The reflecting surface is of a paraboloidal semicylindrical shape, with an area of about 2.5 square metres. It is made up of mirror strips of 400 mm length and 25 mm width. The focussed radiation is made to fall on an absorber tube of blackened copper with an outer diameter of 22 mm enclosed in a glass envelope in order to cut down convection and radition losses. A tracking mechanism is provided. When made on a commercial scale in modular form, these units can generate process steam required in various industries like sugar, food etc. or can be used to run low pressure turbines.

There have been different set ups fabricated, with different rim angles, that is, the position of the absorber with respect to the concentrator.

3. Paraboloid Dish Concentrators: These are of 350 mm aperture, formed from plain glass by thermoforming processes, and silvered at the rear surface. These are made by the CISL Department. Temperatures of about 1000°C can be achieved at the focus, and the dish is provided with a continuous tracking mechanism.

4. Fresnel Lens: Fresnel lenses of 350 mm diameter with a focal length of 210 mm has been fabricated from clear acrylic plastics. The temperature at the focus exceeds 1000°C. Arrangements for cutting master plates of different sizes are being made.

5. Flat Plate Collectors: Flat plate type solar collectors are fabricated out of aluminium roll bond panels or corrugated sheet and tube panels. Collectors are about 1 m x 1 m and are connected to water storage tanks, the water being circulated through the collectors by thermo-syphoning. Tempertures of about 70°C are routinely achieved and temperature can be raised to about 90°C by means of booster mirrors.

6. Selective Surface: Black nickel and black chrome selective surfaces prepared by electro-deposition have been made at the Metallurgy Department. The coatings are made on nickel plated mild steel or aluminium with zinc conversion coatings.

For mild steel base, the mild steel samples are mechanically polished to obtain a smooth surface, and brightnickel wsa first electroplated from a bath containing nickel sulphate, boric acid and nickel chloride. The initial coating by bright nickel is necessary in order to protect the base metal from corrosion, to help easy electrodeposition of the black coating, and to provide a base of low emissivity. After the bright nickel coating, black nickel can be coated from a bath containing $NiSO_4$ $6H^2O$ $ZnSO_4$; $7H_2O$ $(NH_4)_2SO_4$ etc. Black chromium can be deposited from a bath containing CrO_3, $BaCO_3$ and small quantities of sucrose and fluorosilicate.

Aluminium samples are polished, degreased, cleaned with dilute NaOH, dipped in dilute HNO_3 + H_2SO_4 and given a zinc conversion coating using

sodium zincate. Black-nickel and black chromium can be successfully deposited on the zinc coated aluminium.

Reflectivity values in the 0.1 to 0.5 micrometer range can be as low as 0.2% for the black chromium coatings. The sizes of the samples are to be increased, and sizes of 10" x 10" (25.4 cms x 25.4 cms) are to be shortly achieved.

WIND MILLS FOR WATER PUMPING

Work at the institute has resulted in a successful low cost design utlising appropriate technology and utilising material and labour available in the rural areas. A prototype of this has been operating in Ungra, a village about 100 kms from Bangalore, since September 1977 and has been pumping about 2500 litres of water per day since that period.

The wind mill consists of two A frames spaced apart by connecting frames with a savonius type rotor supported between the beam centres. The lower parts of the A frames are triangulated by diagonal members. The first prototype used cut timber of 5 cm x 10 cm nominal size and the second prototype used casuarine poles, obtained from trees near the site.

The rotor, of the savonius type, consists of a vertical shaft of galvanised steel pipe with suitable welded end fittings. The shaft is supported by a simple self aligning brass bush at the top and by a ball bearing at the bottom. The bottom end of the shaft can carry a power take-off drum and an end crank for driving a pump. Near the ends of the shaft are welded fittings to which can be bolted wooden end plates. Wires strung between the end plates (16 in number) form the support system for the rails, which are of jute canvas painted with tar and water proofed. The wires at the trailing edge incorporate twisted joints just below the top end plate. Each twisted joint will unwind at a definite and predictable tension in the wire, and if this happens in a high wind, the sail will open out, reducing the rotor speed and unloading the structure thus acting as a safety measure. The sail area is roughly $8m^2$.

The pump consists of a pneumatic tyre casing (scooter tyre) blocked by two discs at the ends, creating an enclosed volume. Relative displacement between the discs changes the enclosed volume and can be used as the pumping chamber of a positive displacement pump by adding a pair of non return valves and pipes. The pneumatic tyres are generally designed for operation at an internal pressure of about 2 kg/cm^2, which corresponds to about 20 meters of water. Hence the tyre pump can be used for water pumping upto about 20 meters.

The total costs of the pump came to about Rs.2990/-, of which Rs.1850/- was materials cost and Rs.1140/- for labour. Many villagers who have seen the wind mill have expressed the opinion that they can share the labour costs on a mutual help basis, and that they can build the wind mill for a cost of about Rs.2000/-.

BIOGAS PLANTS

A consensus now exists that biogas plants for individual families is beyond the reach of all but affluent farmers. Also the quantity of cement and steel used in the standard construction are considerable. Hence attempts are being made to construct community biogas plants, and to modify the designs in such ways as to use substantially less quantities of cement and steel.

The village of Pura was selected for the study of the feasibility of community biogas plants. The village has a population of about 340 distributed in 60 house holds, and a cattle population of about 146. The wet dung availability is about 1300 kg/day, which corresponds to an yield of 45 cubic meters of biogas per day. Preliminary estimate suggest that this is sufficient to meet all the cooking needs of the village, which currently requires about 570 kg of firewood/day. Enough gas is left over to run a kirloskar 5 HP biogas engine for 5 hours for lifting water for household water requirements (6000 litres/day) for electric generation (3 hours per day, to light two 25 watt bulbs per house) and for driving a ball mill to produce rice husk ash cement (40 tonnes per annum). Detailed cost estimates are being worked out.

ASTRA has been designing a modified biogas plant of about 2.5 meters diameter and 2.5 meters depth, which can be constructed for about 60% of the cost of conventional designs with the same yield. Attempts are being made to separate out the carbon dioxide from the biogas. This would make the gas a better fuel and generate CO_2 which can be used for other purposes.

Another ASTRA innovation has been the solar water heater consisting of a water tank covered with a transparent plastic cover. The tank is situated on the roof of the gas holder of the biogas plant. The water gets heated to about 40-50°C at about 3 PM, and can be used for hot charging the digester, which makes for much better gas yields. The roof top water heater reduces the heat loss at night from the biogas plant, improving efficiencies. As a further bonus, about 4 liters/day of distilled water are produced per sq.m of the plastic cover.

OTHER AREAS:

There are other projects in operation at the Institute which should have a substantial impact on India's energy situation. One project aims at forecasting the energy needs of India in the various sectors such as industrial, agricultural, domestic, transporation etc. and seeks to show how such needs can be reconciled with resources available. Considerable emphasis is placed on the prospects for renewable resources of energy, and efforts are made to monitor the current progress in various energy generation areas and to predict the course of future progress. Conceptional design of a renewable resources based rural agro-industrial energy complex is attempted, this will seek to satisfy the requirements of the majority of the population of India based on a needs-based strategy. It is hoped that a formulation for a coherent, balanced, energy strategy for India will emerge from this work.

Another project attempts to identify the fuel savings, (especially of petroleum products) that would be obtained by substituting aluminium for steel in various structural components of railway wagons and passenger coaches. Preliminary estimates suggest that substantial savings may be achievable by this process.

There are many other programmes, at ASTRA as well as in other departments on renewable resources in materials as well as energy. For example, some of the student dissertation projects are on: (1) modelling of biogas units, (2) production of sodium silicate from rice husk (3) plastics from castor oil, (4) edible cellulose from rice husk (5) cellulose fiber from groundnut shells, (6) energy survey of building materials (7) rammed earth construction, soil cement blocks and stabilization (8) solar air conditioning (9) heat pipes and similar topics. Faculty research programs include (1) vapour pulse pumps (2) small scale rural industries such as soap productions, silk worms etc. (3) low cost building construction and (4) educational aids for science teaching etc. The highlights of the work of the past year at ASTRA include, apart from the successful completion of the windmill, such projects as modelling of biogas units in corporation and successful field testing of failure reducing modifications in the hand pumps for pumping water supplies in the villages, production of sodium silicate from rice husk, elaboration of a theory for dimensioning biogas plants and for the heat transfer processes in these plants. Plastics from castor oil, an extensive survey on energy consumption patterns in house holds in 6 villages. This comprised resource survey of animal, human, commercial and non-commercial sources of energy and the distribution of these resources in the various consuming sectors such as agricultural, domestic, lighting and other miscellaneous uses. This would provide a data base for the feasibility studies of rural energy centres.

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INDIAN INSTITUTE OF TECHNOLOGY
Bombay

Research and Development work in renewable energies is being pursued at the various departments attached to the institute. The investigations form a part of the graduate, post-graduate and doctoral programmes. Several time-bound sponsored projects have also been undertaker. The main thrust in the solar energy utilization has been in the following major areas:

Solar Refrigeration

A 0.5 ton continuous ammonia water absorption system has been completely built and tested. The hot water supply is at 95°C from flat-plate collectors and it is possible to keep the storage room between 2 to 5°C. Performance studies of the sub-systems are in progress. It is envisaged that these studies will give adequate data for scaling up the design and evaluating the performance of economical size units.

Prime Movers

In this area, two projects are in progress. A 20 kWe freon-turbine running at 3000 rpm alongwith its control and sub-systems is being assembled and for testing purposes a conventional heat source is used. A 5 kW freon turbine has already been designed and tested.

A stirling engine of 200-250 watts capacity using alternative source of energy like biogas or solar energy has been designed and is being assembled. It will be a completely sealed unit, incorporating a pump or a linear generator. It would be pressurized at 20 atmospheres with helium gas. The unit would be ready soon for sub-system evalution, and performance studies.

Solar Energy Storage

A project relating to the design development of a 300 kW-hr latent heat solar energy storage system to work at 300°C for multiple end uses is under

consideration. Latent heat storage system has the advantage of compactness and operational advantage of nearly constant storage. Based on the computer-aided analysis and experimental results of the above system, design specification will be formulated for a 6000 kW-hr latent heat storage system for a 20 Kwe solar power station.

Wind Energy

A 200 watt windmill alongwith the controls has been designed and is ready for installation on a fabricated tower on the fringe of the "Powai Lake", as a demonstration unit. It would be coupled to a pump and data will be collected regarding its efficiency and wind availability.

Concentrating Collectors

It is proposed to develop a cylindrical parabolic concentrarting collector module. It will have an east-west axis and an aperture of approximately $4m^2$ (1m wide x 4 m long). The reflector will be made of curved glass mirrors. The accuracy of the reflecting surface and its orientation will be investigated to provide a good interept factor. The concentration ratio will be around 10 and the fluid outlet temperatures between 150°C and 200°C. As part of the project, it is also proposed to evolve a standard procedure for testing and specifying concentrating collectors.

Solar Chargeable Battery (Saur Viddyt Kosh)

Research is being conducted to develop a chargeable (Storage Type) Solar Electrochemical Battery. A cell has been developed of type $\frac{\text{Ba-Tio}}{\text{Pt}}$ /Ce^{3+}, Ce^{4+} //Fe^{3+}, Fe^{2+}/pt. This cell gives 0.62 volts and 0.1 mH/Cm^2. It has been named as Saur (The Sun) Viddyt (Electricity) Kosh (Battery) to distinguish it from photovoltaic and photo-electrochemical cell. Efforts are now being made to improve the power of this cell. Materials under study are Fe_2O_3, $YFeO_3$, WO_3, CR NIO_4, La CrO_3 and TiO_2. These materials are expected to give higher photocurrent and hence efficient charging rate.

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INDIAN INSTITUTE OF TECHNOLOGY

Kanpur

Research and Development in solar energy started in the year 1975 at I.I.T. Kanpur. It recognized that emphasis should be laid on the development of experimental models of solar devices for commercial exploitation and that product development be based on proper design criteria satisfying functional requirements under indigenous conditions, keeping in view the social and economic constraints that operate. Thus, theoritical research work has been taken up inorder to gain an insight into the systems designing. Involvement of scientists and technologists from various departments of the Institute is, thus, obvious. A summary of work being carried out in different departments of the Institute is reported here.

Solar collector is a vital component of all solar thermal devices. Flat plate collector of various designs using water and air as transport media in the temperature range below 100°C are being studied by the Department of Mechanical Engineering on the following lines:

1. Effect of fluid flow rates through collectors, including wind velocities and other parameters;
2. Heat losses through a collector;
3. Mathematcal modelling for optimisation of collector designs and predicting their performance characteristics;
4. Environmental and architectural integration of collector systems for water and air heating for various applications.

Specific project on "Design and development of solar water heating systems for Indian conditions" sponsored by Fibreglass Pilkington, Bombay, is under progress. Boh thermosyphon and forced circulation typed solar water heating systems for domestic and industrial applications have been developed and tested at the laboratory level. The Department of Mechanical Engineering is also offering an elective course on "Solar Energy Thermal Processes" to its final year students. A solar energy laboratory of the department is being developed to offer the facility of fabricating and testing various solar devices. A number of post graduate students of the department have worked for their

Master's degree on projects concerning solar dryers for agricultural products, solar water heating systems and solar pumping for irrigation purposes.

Along with a group of faculty members in the Department of Chemical Engineering, graduate and post-doctoratal students are also working on experimental and theoretical aspects of solar water pumping, nocturnal radiation water cooler cum solar water heater, comfort conditioning, boiling solar collectors and large scale solar power generation suitable for the arid and semi-arid zones. Besides several central facilities of the institute that are available to carry out solar energy work, the department also possesses a laboratory which is equipped with instruments like Epply precision pyranometer and infrared radiometer alongwith electronic integrator and digital recorder.

Data acquisition system is also expected to be available soon. The department is offering a graduate course on "Topics of Energy". Work on projects sponsored by Tata Energy Research Institute and Hindustan Brown Boveri (HBB) Baroda is underway. Also, one of the faculty member is a consultant to HBB, for their solar energy projects.

Theoretical as well as experimental work on Solar Cells is on-going in the Deartment of Electrical Engineering, for the last few years. Various kinds of cells are being studies. These include p-n junction solar cells, SB (Schottky barrier) and MOS solar cells. Recently, work has also started on ITO (indium-tin-oxide) and electrochemical solar cells. Experimental work was initiated on a large scale about two years ago, by the projects sponsored by HBB (Hindustan Brown Boveri) and DST (Department of Science & Technology). Encouraging results have been obtained. Several p-n junction solar cells have been developed for use under an insolation of 40 to 60 Suns. Use of concentrated sunlight on these cells is expected to bring down the current cost of solar cells from Rs.120/- peak watt to about Rs.15.25 peak watt. The p-n junction solar cells developed show an efficiency of about 12.0 percent without any anti-reflection coating (ARC) under normal insolation which is equivalent to an efficiency of 16.0 to 17.0 percent with ARC. Research on MOS solar cells is continuing. Already MOS solar cells have been fabricated on device grade

polycrystalline wafers with about 9.0 percent conversion efficiency, an open-circuit voltage of 480 mV and a short circuit current density of 29.0 mA/cm^2 without the application of any antireflection coating. Initial results on electrochemical solar cells are very promising. These show very high open-circuit voltages, e.g. nearly 1.0V in case of silicon and 1.3V in case of GaAs. However, the main problem of degradation of the semi-conductor electrode remains to be solved.

Communicated by: Dr. H.C. Agrawal, Professor of Mechanical Engineering, Indian Institute of Technology, P.O. I.I.T., Kanpur 208 016.

INDIAN INSTITUTE OF TECHNOLOGY
Agricultural Engineering Department
Kharagpur

Solar Energy for Parboiling & Drying of Paddy

A system for parboiling and drying of paddy using solar energy was designed, developed and tested. A cylindrical parabolic collector covered with aluminium foil was found to be economical and efficient. An aluminium absorber coated with 5% cupric nitrate solution gave L/E ratio of 88.00. The use of glass cover on the absorber tube increased the concentration of sun's radiation by 15%. It gave 4% more heat output as compared to polyethylene transparent plastic cover. The paddy was successfully parboiled in receiver pipe of concentrator in 2 hours during May and in 4.5 - 5 hours during December. It took 3.25 - 3.5 hours to parboil paddy in a separate insulated tank filled with hot water heated by solar energy. The milling quantity of solar parboiled paddy was almost similar. The cooking quantity of solar parboiled rice was intermediate between raw and conventionally parboiled rice.

Studies on Sun-drying of high moisture raw and parboiled paddy on the floor were also carried out. It was concluded that Sun-drying should be carried out at least in two stages. The termination point of first stage is about 16 percent moisture content (wet basis). It should be followed by 3 hours of tempering for subsequent stage of drying. The optimum thickness of raw and parboiled paddy for drying was found to be 2 cm. Use of transparent cover about 3 cm above the paddy surface decreased the drying time to 2/3 that obtained without any cover. The sides of the cover should slope to about 10° with the horizontal to remove condensed water from the cover to a place, a little away from the paddy surface.

Studies were also conducted on mechanical drier using solar energy heated air for drying raw and parboiled paddy. A flat plate (roof type) solar collector of 4 m x 3 m worked as air-heater. The solar collector was coupled to a bamboo drying chamber by means of a blower and air duct. The solar collectors with and without glass cover were used to dry the raw and parboiled paddy.

The raw paddy was dried at 48°C + 2°C and it took 4 hours for reducing moisture content of paddy from 22 percent to 14 percent with three hours tempering in between two stages of drying.

The parboiled paddy was dried by using 60°C air temperature. The average drying rate in percent moisture removed per hour was 2.8% with the total and head yield being 74 and 67.2 percent for IR-8 variety and 72.6 and 66.8 percent for Jaya variety. The total drying times were 8 hours and 7.5 hours respectively for both the varieties.

Design, Development & testing of a Groundnut Solar Drier

Three types of flat plate air heaters i.e. collector with no glass, one glass and two glass covers were tested for their comparative performance with respect to various parameters of collector tilt, air flow rates, and wind velocity. The collector with one glass cover was found to be the most desirable for the purposes and tests were conducted with this collector to dry groundnut pods having high moisture content.

Development & Testing of Solar-Water-Heater

Attempts have been made since 1975 to develop a solar-water-heater incorporating a flat plate collector. The heat-absorber was made out of two T.I. Sheets, fastened together, of 2.4 mm x 0.80 mm size with 200 litres of water heating capacity at 65°C. The total cost of the water heater was about Rs.900.00. The water heater was tested with and without glass cover. The maximum temperature obtained was 78%C without glass cover and 92°C with a glass cover under clean sky conditions during the first week of May, 1976.

Solar Energy for Milk Pasteurization

In conventional pasteurization method, every particle of milk is heated to at least 63°C and held continuously at or above this temperature for atleast 30 minutes or to atleast 72°C and held continuously at or above this temperature for atleast 15 minutes. After pasteurization, this milk must be cooled quickly

to 7°C or less, sufficiently low to retard the growth of surviving organisms. It is also essential that the product be protected from contamination. The energy used for heating is under full control and a particular temperature can be maintained by controlling the rate of energy input.

In this newely developed system, run by solar energy, the milk is heated in a flow tube as it flows under gravity. The rate of energy input varies with the times of the day. The project aims at determining the optimal flow rate of milk passing through a black coated absorber tube located at the axis of a cylindrical parabolic reflector for varying intensity of solar radiation.

The reflecting surface is made of a number of glass-mirror strips. A secondary reflector is used to focus the wider strips of image formed by the primary reflector to a comparatively narrow strip. This secondary reflector also helps in heating the milk-tube from all directions. The focus of the secondary reflector is the axis of the milk tube.

The cross-section through which milk flows is an annular section between two concentric pipes. The annular section was preferred over other sections for better and uniform heating of milk. After the milk is heated, it is held in the holding units. Milk takes about 5 minutes to flow through holding unit. The holding unit was made by insulating a stainless steel cylinder from all sides with asbestor rope and asbestor powder. After passing through the holding unit, the milk is cooled to 5 - 8°C in cooling unit.

Phosphatase test was conducted on the pasteurized milk to determine the extent of pasteurization attained. The milk was successfully pasteurized using solar energy.

Solar Refrigeration System

A cooling system of 1 ton refrigeration capacity based on continuous Lithium bromide-water cycle, operated by solar energy has been designed specially for rural areas in India where electricity and other types of energy

are not available or scare. The system may be used for preservation of agricultural and food products at temperature about 2-3°C.

Absorption refrigeration system is essentially a heat operated device requiring small amount of work transfer. Lithium bromide-water absorption cycle is well suited for a solar energy system when the evaporator temperature required is not less than 0°C. The refrigeration system is designed to operate with a cooling water circulating pump, air circulating fan over the evaporator and two solution circulating pumps. The power requirement for the operation of these mechanical devices is small and may be obtained from either conventional electric motor or small internal combustion engine. In this design, a cylindrical parabolic collector has been considered as the heat source. A water cooled horizontal double pipe condenser and an extended surface air cooled with forced air circulation have been found suitable for this system.

In this system, two arrangements have been considered : (i) Liquid refrigerant (Water) and strong absorbent solution generated in excess, during the period of sunshine is stored for use at the time of inadequate or no sunshine. (ii) Provision is made to transfer heat to the generator from fuel burner when sunshine is not available and when the stored refrigerant and absorbent solution are exhausted.

Use of Solar Energy for Lifting Water for Irrigation

A solar water lift pump is designed to operate on vapour Rankine cycle, using pentance (a low boiling point liquid) as the working medium. The pumped water is not allowed to mix with the working fluid. The device consists of a flat plate collector, vapour chamber, bellow chamber and water chamber. A condenser cooled by water is also provided. A pressure valve is used. This returns the condensate by equalising the pressure in the vapour chamber and condenser after the completion of the work.

During the operation, the tubular grids of the collector and about half of the vapour chamber are filled with pentane. The system gradually warms up by solar heat. The vapour pressure and temperature in the vapour chamber

increase during this period upto the required valves. Then a three valve is operated to allow the high pressure vapour to enter the bellow. The bellow expands and water is delivered during the period. Next the three way valve is operated such that it opens the passage from bellow to condenser. The vapour from the bellow then passes to the condenser where it is liquefied due to cooling by the water being pumped. This cycle is repeated as long as there is sunshine and water is delivered in each cycle.

Design & Development of a Water-Lifting Pump

A water lifting pump to lift water upto a head of 1 m was designed and fabricated this year. The pump was based on the drinking bird principle operated on the temperature-difference created on two ends of an arm pivoted on its stand. The working fluid to operate the device was freon-20.

Design & Development of a Solar Rice Bran Stabilizer

Rice bran is a potential source of oil and protein. It contains about 20-25% oil. But the rice bran gets deteriorated within a very short period because of the lypolytic hydrolysis of the oil due to the presence of an enzyme called lipase. Because of this activity, the free fatty acid content of the rice bran oil increases at a very high rate making the oil inedible. In order to make the rice bran oil edible, it is necessary to arrest this activity by a process known as stabilization. This process involves the heating of the bran particles uniformly at a particular temperature for a particular period.

An effort was made to stabilize both raw and parboiled rice bran by dry heating, using solar energy. The uniform heating is accomplished by simultaneous mixing and conveying in a screw conveyor by concentrating the sun's rays on the trough surface, from a parabolic cylindrical solar concentrator.

The solar rice bran stabilizer has been designed for capacity of 20 kg of bran per hour to match a rice mill of 0.5 tonne hour capacity. The screw of the screw conveyor is 2.25 m in length, 0.1 m diameter, 0.08 m in pitch and rotates

at 7 revolutions/minute. The rotation is achieved by a motor, coupled with a reduction gear and pulleys. A handle is also provided for rotating the screw conveyor with hand in case of non-availability of electricity. The parabolic cylindrical solar collector is designed to heat the bran at 105 to 110°C. The collector is of 2.25 m in length, 2.4 m in apperture width and 0.6 m in focal length. The rim angle is kept at 90°C for maximum concentration. The collector is hinged at the two ends of the supporting frame to facilitate tracking the sun.

It was concluded that parboiled rice bran can be stabilized at 105°C by heatng for 5 minutes or at 90 to 95°C for 15 minutes, to store it safely for at least one month. Raw rice bran can be stabilized at 110°C for 5 minutes to store it safely at least for 20 days. The cost of stabilization has been calculated to be 7 paise per kg of bran.

Extraction & Purification of Solar Grade Silicon from Rice Husk

India produces 13 million tonnes of rice husk annually. Presently, only a fraction of this huge quantity is being utilized for useful purpose mainly as fuel. The main advantage of using rice husk are (1) The silica in the husk is in a finely dispersed, amorphous form and is chemically active (2) It has extremely low boron content as compared to other natural silica sources. (3) Pyrolised husk has both silica and carbon present together (also in well mixed form) and therefore, does not require additional coke which in turn minimises the possibility of further contamination. (4) The chlorination process of pyrolised husk is exothermic and thus the whole process of obtaining $SiCl_4$ straight from rice husk would require less energy.

Two routes are being followed to obtain polysilicon from rice husk.

1. First, chlorinate pyrolised husk to obtain $SiCl_4$, purify and reduce with pure Zn to obtain polysilicon.

2. Direct metlo-thermic reduction of white rice husk with pure Al.

The work was initiated in 1975 and is continuing.

List of Publications/Thesis:

Year	Title of Thesis	Name of the Student	Name of Supervisor
	Ph.D. Thesis		
1978	Utilization of Solar Energy for parboiling and Drying of paddy (under evaluation).	O.P. Singhal	Pro. C.P. Gupta
	M.Tech. Thesis		
1974	Development and testing of Groundnut Dryer with Solar Energy.	Balwant Singh	Prof. T.P. Ojha
1975	Design, fabrication and testing of a parabolic cylindrical Solar heat collector.	M.P.S. Sirohi	Dr. M.D. Pahuja
1976	A Solar water lifting Device.	J. Singh	Prof. T.P. Ojha
1976	Design and testing of a self tracking parabolic cylindrical solar collector and winston collector.	A.S. Myles	Dr. M.D. Pahuja
1977	Comparative performance of tracking and non-tracking type solar collector.	S.K. Nanda	- do -
1977	Utilisation of solar energy for Milk Pasteurization.	M.M. Pandey	Prof. C.P. Gupta
1978	Design, development and testing of Solar rice bran stabilizer.	P. Mishra	Prof. C.P. Gupta

Communicated by: Professor C.P. Gupta, Agricultural Engineering Department, Indian Institute of Technology, Kharagpur.

INDIAN INSTITUTE OF TECHNOLOGY

Madras

Various departments of the Institute are involved in developmental research relating to renewable sources of energy. These include Refrigeration and Airconditioning Lab, I.C. Engines Lab, Hydro Turbo machines Lab, Thermal Turbomachines Lab, centre for Rural Development etc.

Solar Refrigeration

1.1 An intermittent refrigeration system with ammonia-water combination has been tested. Modifications of this system for operating with ammonia - sodium thiocyanate are being carried out. The design capacity of the unit is 8 kgs of ice per day.

1.2 A continuous absorption refrigeration system with ammonia-sodium thiocyanate of following specifications has been developed:

Capacity	1 Ton
Generator temperature	95°C
Absorber/condenser temperature	40°C
Evaporator temperature	-5°C

The preliminary testing of the system is completed and it has been handed over to BHEL, the sponsors of the project, for long term testing and commercialisation.

1.3 A continuous absorption refrigeration system with ammonia-water has been developed. Preliminary testing is completed and the long term performance tests are underway.

The design specification of this unit developed under an Indo-German joint project with University of Stuttgart are:

Capacity	1.5 Tons
Generator temperature	90°C
Absorber/condenser temperature	35°C
Evaporator temperature	-5°C

1.4 Analytical studies on the vapour jet refrigeration systems operating on solar energy have been completed. These have yielded the data on the applicability of different working fluids, operating limitations and the basis of thermal design. An experimental system is being fabricated.

1.5 Studies on new refrigerant : Absorbent combinations for solar refrigeration systems have been carried out. These include the generation of thermodynamic property data, analysis of the system performance and determination of operational limitations.

Solar assisted heat pump systems

2.1 Computer simulation of vapour compression and vapour absorption type SHAP systems have been carried out to study the performance characteristics of various working fluids under different operating conditions.

2.2 Two vapour compression type SAHP systems with working fluids R11 and R114 have been developed and are being tested. These are for high temperature (95°C) industrial applications. The studies also aim at the application of conventional compressors for heat pump duty.

2.3 A vapour absorption heat pump system with R22-Dimethyl formamide for space heating/cooling applications have been fabricated and is under-going tests.

Solar thermal power

3.1 A 10 kW solar power plant has been installed under a joint Indo-German agreement with the Refrigeration and Airconditioning Laboratory of Indian Institute of Technology, Madras, BHEL R & D Division, Hyderabad, and Space Division of Messerschimitt-Bookow-Blohm as working partners. This is an autonomous power plant suitable for supplying electricity to rural areas. The preliminary tests are completed and the long-term performance tests are being carried out.

Energy collection and storage

4.1 Two large flat plate collector fields (800 m^2 and 100m^2) are used for carrying out experiments. Larger of these collector fields feeds the solar power plant.

4.2 Computer simulation and experimental studies on model thermal energy storage tanks with stratified water have been carried. Energy storage tanksof 16 cum. capacity (2 nos.) and 33 cum. capacity have been installed and tests on stratification are being conducted.

4.3 Experimental studies on heat pipe collectors with different types of working fluids are being carried out.

4.4 A flat plate collector performance test rig has been fabricated. This also facilitates comparison oftwo collectors under identical operating conditions.

4.5 Experiments are being carried out to generate heat transfer and pressure drop data for flow in solar collector chanels. These experiments in their final phase will yield the data useful in the design of flat plate collectors.

Alcohols as Engine Fuels

5.1 Dual Fuel Engines: In this type of engine, alcohol is fed alongwith the incoming air in a dual engine and ignited by a pilot spray of diesel oil. The 4-cylinder diesel engine of the Standard-20 micro-bus was converted to work on this principle and the performance evaluated on dynamometer and in road tests. The results of this work were presented at the Society of Automotive Engineers (SAE) International Congress held in Detroit, U.S.A. during February 1981.

Currently a Ashok Leyland 6-cylinder automotive diesel engine has been converted to work on this principle and its performance is being evaluated.

5.2 Surface Ignition Engine: Alcohols, even though they have a high self ignition temperatures, have however a peculiar tendency to ignite easily from hot surfaces. This tendency is a problem in alcohol SI engines, since it causes

pre-ignition. A new type of engine called the surface ignition engine has been developed which turns this weakness of alcohols into an advantage and enables diesel engines to be operated at normal diesel compression ratios. Currently further development work is proceeding on this engine. It is also being attempted to coat the surface ignitor with catalysts so that the combustion can procede faster.

5.3 SI Engine: A stratified charge alcohol engine has been developed and is under testing. The exhaust emission from this engine is also being evaluated.

Hydrogen

Hydrogen is considered promising alternative fuel. The dual fuel engine employing hydrogen as the inducted fuel is being tested and developed for further improvements in thermal efficiency and hydrogen substitution level. The results of this work have been accepted for publication in the International Journal of Hydrogen Energy.

Biogas Technology

Biogas is regarded as a potential source of energy for rural areas. A biogas plant has been set up in the Institute and spark ignited engines and dual fuel engines are being developed and tested. The results of these investigations have been reported in several papers (Also see Section 9).

7.1 Biogas Digesters

The fundamental process of anaerobic digestion is also of interest since it affects the biogas yield. Accordingly small scale digesters have been fabricated for the use of the Chemistry Department in order to study the various parameters affecting biogas generation.

Tidal Energy

In tidal power plants, energy available due to the level difference between the flood and ebb tides is utilised for power generation. The economy

of these plants can be improved by choosing a tubular machine and using a completely reversible axial flow pump-turbine. This machine works as pump and turbine for both directions of flow, thus having the four models of operations. A project for research, design and development of a suitable turbine has been successfully completed. The experimental results at the best efficiency point are detailed here:

Specifications	Experimental Results	
	Pump	Turbine
Head, m	7.59	8.35
Discharge, m^3 /s	0.204	0.42
Power, hp	27.4	36.2
Speed, rpm	2000	2000
Specific speed	821	833
Shape number	685	694
Efficiency	0.755	0.775

The efficiency will be much higher in the prototype, since the size of the prototype machines will be much more than the model developed here.

8.1 Mini-hydro power plants

Considerable work has been done to develop the indigenous knowhow for designing turbines for Mini-hydro power plants. The development of a bulb turbine of high specific speed is nearing completion. This would be of immense use in microhydropower plants and also in large low head power plants.

The design and development project on bulb turbines has been sponsored by BHEL, Bhopal. The design for the turbine model having the followig

specifications has been completed :

Head = 2.1 m
Discharge = 0.245 m^3/s.
Specific speed n_s = 1255,
Speed = 1275 rpm
Power = 4.55 kW

The model is being assembled and the tests will be conducted shortly.

8.2 Thermal Turbomachines

The Thermal Turbomachines Laboratory, has been engaged in carrying out research in the field of fans, blowers, compressors, steam and gas turbines. Research programmes are aimed at minimising the energy losses in turbomachines and effectively increase the efficiency of energy transfer.

A research project on centrifugal compressors (under the Indo-German joint research programmes during 1977-1980) directed in trying to improve the impeller exit flows and reduce the wake and jet mixing losses at impeller exit. The flow pattern at diffuser inlet was improved and the non-uniformity of flow was minimised. The project was recommended for further research.

Investigations on a single stage axial impellers with freely rotating inlet guide vanes have been carried out, to improve the stable operating range and minimise energy losses while the machine is to operate off-design conditions. The application of this research programme would be for irrigation pumps where suction head would be varying;. cooling and ventilation fans which are required to operate away from the design conditions.

Research in turbine blades is carried in two dimensional and three dimensional cascades to evaluate he different loss mechanisms, boundry layer flows, secondary flows and losses. Knowledge of different loss mechanisms and their sources, would help to design better turbine blade profiles which will help energy generation more efficiently. Several research programmes have been carried out in the area. Testing of a steam turbine exhaust casing has been successfully completed and suitable modifications have been suggested to reduce the pressure losses and increase the turbine efficiency.

Cooling fans for use on electrical machines and fans for tractor motors have been designed. Of the sponsored research schemes, one is aimed at a study of boundry layer treatment in centrifugal compressors, which will ultimately result in reducing impeller energy losses. A second one is for developing an efficient centrifugal compressors, impeller suitable for a turbocharger. The present work is also related to the design and development of a high speed centrifugal impeller.

Centre for Rural Development

Development of Biogas Technology has been split into three aspects. They are (1) generation of gas based on various types of input materials (cowdung, water hyacinth, algae, kitchen wastes, duckweed, etc.,) and other types of 'doping' agents such as urea, phosphates, etc (2) improvement of quality and quantity of gas with minimum cost input by studying various parameters involved (3) utilisation of biogas.

Data regarding generation of gas with cowdung as well as waterhyacinth are being collected, by measuring the temperature, pressure and pH values of the input in the digestor under anaerobic conditions. Three types of digestors have been constructed (i) a 2 cum. digestor of modified janta type, in which cowdung has been fed as input. A manhole was provided in the design and arrangements for preventing leak were undertaken, (ii) a 5 cum, vertical type floating drum digestor based on KVIC design made (iii) a 28 cum. horizontal type floating drum digestor based KVIC design. The input material for these two has been cowdung. Experimental digestors to the extent of a few litres capacity have been used to gather particulars on water-hyacinth, and cowdung. Experiments are in progress for the production of biogas harnessing the methanogenic potential of thermophillic bacteria. Study has been made on the quantity of generation by using urea.

The quality of the gas is improved by scrubbing, so that higher percentage of useful gas is obtained. The biogas that comes out of the tower containing moist iron filings is essentially devoid of H_2S. The only other impurity that it contains is CO_2. An aqueous sodium carbonate-bicarbonate

solution can be used to scrub the CO_2 out of the biogas in a countercurrent packed tower. The reversible reaction

$$Na_2CO_3 + CO_2 + H_2O \longrightarrow 2\ NaHCO_3$$

is utilised in the absorption process.

The reversibility of the reaction enables the regeneration of CO_2, if necessary. Initially the biogas is exposed to an aqueous solution containing sodium carbonate under conditions which favour the formation of sodium bicarbonate according to the above equation: CO_2 is removed from the gas phase and stored in the liquid as bicarbonate. Then the liquid is removed from contact with the gas and is subjected to conditions which favour the decomposition of sodium bicarbonate with the formation of sodium carbonate, CO_2, and water. The CO_2 evolved is accompanied only by water vapour which is easily removed by condensation. Experimental set-up consists of a scrubber (a column designed for the appropriate flow rates, filled with the packing material Rasching Rings 1/4'), a vacuum pump to displace the gas from the holder, a container for the outlet liquid containing the CO_2 and a heater to regenerate the scrubbing liquid.

	Results	Before scrubbing	After scrubbing
1.	50% Solution Na_2CO_3	Flame temperature:550°C	Around 670°C
2.	50% KDH Solution	Flame temperature:600°C	Around 730°CC

Experiments are in progress to develop favourable conditions for effective scrubbing to increse the flame temperature.

The gas generated from 28 cum. plant is used to cook food everyday at a project on rural development undertaken by the Institute at Narayanapuram village. A Kirloskar diesel engine runs for about 3 hours per day by using 85%

of this biogas. The biogas besides being used for lighting directly is also used for generating electricity. A Kirloskar gen-set has been purchased for this purpose. The electricity is used for welding and for the street lights when power from the Electicity Board is not available.

The aim of the work is to generate about 1400 cum. of gas per day at the minimum cost so that this forms a self-contented energy pack for the rural development project.

A study is also undertaken to examine the possibilites of using solar and biogas energy to fulfil the energy needs of a 5000 lit/day milk capacity dairy farm.

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INDIAN INSTITUTE OF TECHNOLOGY
New Delhi

The science and technology plans of the Government of India, identified certain areas of research and development in the field of renewable energy sources. The Institute of national importance like the IITs and the national laboratories were called upon to undertake intensive research and development activity in these areas.

A school of energy studies was set up at IIT Delhi in 1974 to undertake interdisciplinary activities, such as the extraction of alcohols from agricultural waste, substitution of gasoline with various types of synthetic fuels in low powered internal combustion engines, the development of photovoltaic materials, studies of magneto-hydrodynamic power generation, laser induced fusion, liquefaction or gasification of coal and optimisation of production and distribution of conventional electric power system. Recognising the wide spectrum of activities at the school in 1976 it was converted into a national centre for carrying out extensive research, development and instruction in the field of non-conventional energy sources. The centre has been called upon to use, develop and coordinate the existing infrastructure in educational institutions and research laboratories and to act as centre of excellence for advancing frontiers of science and to give the country a viable technology.

The research and development activities of the centre spreads over all science and engineering departments of the institute. The institute is well equipped with laboratory and computer facilities including recently acquired ICL-2960 computer and several mini-computers from ECIL, Hindustan and DCM.

Significant progress has been made by the centre in the last four years. A brief description of the programme of work is given below:

Solar Energy Utilisation

One of the main activities of the centre is in the field of solar energy utilisation which can broadly be classified into three categories namely (i)

Thermal utilisation, (ii) Direct conversion of solar energy into electricity and (iii) Thermal modelling.

Solar Collectors

An effective flat plate collector for water heating has been developed. In this study various plate (fin) materials, like copper, aluminium, steel and galvanised iron (GI) of different thickness, duct shapes like circular, triangular, oval, square, hexagonal, rectangular of different diameters and different spacings, etc. are considered. Design parameters for the optimum collector (in terms of maximum energy per rupee) have been obtained.

Hot water systems each consisting of six collectors with a daily capacity of 800 ltrs are being installed at the terrace of the student's hostels.

In contrast to the relatively expensive solar water heating systems which consist of separate collector and storage units, the institute has pioneered concepts in which the same unit serves for collection and storage of solar energy. Thus glazed blackened GI water tank insulated at the bottom and glazed blocks of concrete, sand or ground embedded with plastic tubings have been extensively investigated; a domestic model has been developed for commercial exploitation.

Linear Fresnel Lens

A process for manufacturing plastic linear fresnel lenses has been developed. With this development it is possible to build linear solar concentrators (equivalent to cylinderical lenses) of 1 m width and of any desired length. The individual lens piece is 50 cm x 30 cm. A die has been designed and fabricated for producing these lenses of focal lengths 1 m and 0.5 m. The system has the potential to produce working temperatures in the range 150°C-200°C.

Selective Coatings

To increase the performance efficiencies of collectors the centre has by now developed several methods for producing selective coatings of different

types on galvanised iron, mild steel, stainless steel, copper and aluminium. The coatings have been deposited using techniques of electroplating, electroless deposition, chemical solution growth and spraying. The various coatings exhibit high absorptance of 0.90 to 0.95 in the solar spectrum and low emittance of 0.6 to 0.12 in the infrared region. A value, called the figure of merit of 15 has been achieved for a new nickel black coating.

Solar Refrigeration

An intermittent solar absorption refrigerator using Ammonia-Sodium Thiocynate was designed and fabricated in May 1978. Refrigeration temperatures upto 3.5°C were obtained. After thorough analysis of these results the design was modified and a prototype was fabricated in March/April 1979. The new system can deliver refrigeration temperatures upto 15°C. The unit operates directly on solar energy with plate temperatures of about 85°C and has the capacity to produce about 10 kg of ice per day. The unit has since been in operation and is being adopted to supply cold drinking water in summer.

Direct Conversion of Solar Energy into Electricity

For the past several years, an intensive programme on the development of highly efficient, low cost, large area thin film CdS/Cu_2S solar cells have been underway. Efficiencies of 8-10% have been achieved on small area cells prepared by both vacuum evaporation and spray pyrolysis techniques. The life of these cells is however comparitively small. Current research aims at reproducing this performance on large area devices and stabilising the cells against degradation by proper encapsulation.

An automatic solar tracking system has been designed and developed at the centre from components available off the shelf within the country. A panel of silicon solar cells with fresnel lens concentration has been mounted on the tracking unit to monitor the insolation throughout the day over the entire year. The collected data is printed out every 12 months.

Solar Thermal Modelling

Solar thermal modelling is essential for understanding, design and optimisation of solar thermal systems. The scope of thermal modelling at the

Institute includes heating and cooling of buildigs, solar water/air heaters, solar ponds, collection cum storage systems, desalination and thermal emissivity of surfaces.

With a view to develop a thermal model of a passive building (heated or cooled by natural means), a systematic study of time dependent heat transfer through walls/roofs of various designs was undertaken. Periodic heat transfer in multilayered slab and single/multiple hollow concrete slab has been investigated. Studies on a three layered, i.e. (i) insulation - concrete - insulation - concrete - insulation, (ii) concrete - insulation - concrete, slab exposed to solar radiation and atmospheric air on one side and room air on the other show that for the maximum load levelling the thickness of the insulation inside and outside the concrete wall should be the least possible in the second case. Similar conclusions are drawn for a single hollow slab, however for a double hollow slab the maximum load levelling occurs when the width of the two air gaps are equal and when the thicknesses of the outer and inner layers of concrete are least (consistent with structural considerations).

In many media (e.g. moist roof/wall) the thermal conductivity and other parameters either change with space or with temperature. To incorporate such effects non linear periodic heat transfer has been studied in finite and semi infinite media. Cooling by evaporation of water over roof to comfort conditioning in summer has been investigated in detail. A general analysis for evaluating the performance of any evaporative system and a review on cooling by water evaporation has been published recently.

Thermal performance of some typical passive concepts, namely Trombe Wall, Water Wall and Solarium has been studied analytically. A thermal model for taking into account the effect of a moveable insulation over the south facing glazing has been developed. The use of such a moveable insulation greatly enhances the thermal performance in each case, the degree of enhancement depending on the type of system being used for passive heating.

A water wall with night insulation performs best thermally. The use of PCM materials in walls for energy storage is also being investigated. Novel concepts like Transwall and a Roof Radiation Trap for passive heating have been analysed and their performance predicted for harsh winter climates.

A non air-conditioned building has recently been modelled to evaluate the overall heat flux into the building. A large scale demonstration project on the solar passive houses is in progress.

Earth sheltered structures are known to provide good thermal comforts in a properly designed house. A knowledge of the temperature distribution inside the ground is, however, desirable from the point of view of estimating the utility of such partially or fully underground structures. The temperature distribution in ground, the surface of which is subjected to periodic solar radiation and atmospheric temperature has been analysed. The theory has been applied to evaluate the thermal diffusivity of the soil from the Fourier analysis of the observed time variation of temperature at different depths. The daily and annual variation of the ground temperature distribution has been calculated for various surface conditions including the effects of moisture in the ground. The temperature distribution in a semi infinite medium with temperature dependent and space dependent thermal conductivity and periodic surface temperature has been analysed; it is seen that due to the inhomogenity of the medium the temperature harmonics are mixed and different harmonics do not propagate independently of each others propagation.

An underground earth tunnel constructed at depths where the ground temperature remains practically constant provides heating in winter and cooling in summer. If the tunnel's surface is kept moist then it results in an enhanced cooling. A detailed study about the performance of tunnels under various conditions has been made and performance charts tabulated.

Solar air and water heaters are the widely used items of solar energy applications. Efforts are being made to design them more efficiently through thermal modelling. Analysis of single and double exposure type of non porous solar heaters and their diurnal response are studied. A black matrix is known to enhance the thermal efficiency of air heaters. A theoretical models for such heaters has been proposed. The use of storage materials in air heaters has also been studied. For conventional flat plate collectors transient study of

their performance has been undertaken. In case of stoppage of the fluid flow the insulation of the system gets damaged. An exact predication can be made with the help of the developed analysis. Analytical studies are also being undertaken for a three zone salt gradient stabilised solar pond and a partitioned solar pond.

Portable Solar Still

Systematic studies on the performance of solar stills, at the Institute of different designs has led to the development of a solar still of an elegant design and high performance. This still is portable and can be fabricated using easily available low cost material. The yield of this still is 50% more than the yield of conventional stills having the same area. The group working on the project was awarded the Hari Om Ashram Prerit S.S. Bhatnagar award for the year 1978. A large unit to produce distilled water to meet the requirements of the Institute has been installed.

Utilisation of Unconventional Renewable Fuels

The Centre is also looking into the possibilities of utilising a large variety of alternate fuels which may be obtained from (i) bio-solar energy (ethanol), (ii) waste organic matter (methanol and bio-gas), (iii) water and air using nuclear or other methods (hydrogen and ammonia), and (iv) coal by the easier method of coal conversion rather than coal liquification (producer gas, methane, methanol). These fuels can be used in a wide range of combustion engines which are used for surface transportation, tractors, irrigation, power plants as stand-by-load units and other miscelleneous applications.

Infrastructural facilities for work in this area includes as well equipped I.C. engines laboratory having a variable compression fuel research engine, multicylinder S.I. engines and C.I. engines and test beds with dynamometers for work on engines of upto 350 H.P. rating. Various types of instruments, pressure pick up indicators and other equipment required for basic combustion studies and engine performance evaluation on utilisation of synthetic fuels like ethanol, hydrogen, ammonia. In addition equipments such as NDIR, DC and CO

analysers, gas chromatographs etc. are also available to study the clean burning characteristics of these fuels.

Experimenal tests have been completed on the utilistion of ethanol and ethanol/methanol gasoline blends in single cylinder and four cylinder automotive type engines. Engine performance and emission characteristics have been compared with those obtained when operating with petrol. These studies have shown the various ways in which ethanol can best be utilised in the present day vehicular engines. The optimum blend which gives best performance has ben found out and the optimum engine operating parameters for various blends as well as for pure ethanol/methanol have been arrived at. The "optimum" ethanol gasoline blend developed by the Institute contains apart from the experimentally determined "optimum" quantity of ethanol, specially developed additives to stabilise the blend denature its ethanol content and give it a distinct colour, odour and burning taste to prevent misuse of its ethanol control. it gives an increase of power output by 3 to 6%. It is found to be a clean burning fuel and produces 10-35% less hydrocarbons and upto 60% less carbon monoxide concentration in the engine exhaust.

Ethanol can also be used as a complete fuel in special ethanol engine designed to operate with higher compression ratios as the engine would have specially designed carburattor and fuel injection system. Computerised studies show that such engines could have about 18% more power, much higher thermal efficiency and cleaner engine exhaust. An ethanol operated scooter has been developed which is capable of operating on ethanol, giving comparable milege to that obtained from gasoline operated scooter. Its exhaust is colourless and contains comparatively very small concentrations of exhaust pollutants.

Use of methanol gasoline blends as also methanol neat has been extensively investigated. Its use in the form of blends can be introduced in existing vehicles although use of methanol neat involves major modifications. Portable ethanol powered engine driven generating set and pump sets of 6 kW capacity have also been developed. Use of ethanol/methanol as a secondary fuel for heavy vehicular diesel engines has also been successfully tried

achieving greater peak power, smoother engine operation and cleaner exhaust with upto 50% full load energy substitution by ethanol.

Considerable amount of experimental work on utilisation of ammonia in both S.I. and C.I. engines has been completed. It has been established that it is feasible to convert and operate exisiting engines with ammonia after suitable modifications. The design/modifications have been standardised for commercial use.

Several methods are being tried for using hydrogen in conventional engines. These include use of a third valve to inject hydrogen directly into the combustion chambers, injecting the regulated supply directly into the inlet ports, and using a modified gas carburettor. All these are being investigated in detail. Hydrogen supplementaton in existing vehicles has been tried with very encouraging results as it permits burning of ultraclean mixtures with consequent fuel economy and reduced exhaust HC and CO emissions.

Benzole is a comparatively inexpensive byproduct of tar produced during the preparation of metallurgical coke. Experiments have been carried out on the use of benzole-gasoline blends in existing spark ignition engines with very promising results.

Work on producer gas has been in progress for quite some time. In the light of the experience gained with the experimental producer gas plant designed and fabricated earlier, some design improvements have been made and the new version permitting continuous feeding has been fabricated. Engine modifications are also being standardised for efficient utilisation of the gas.

Existing small horsepower CI engines have been modified to achieve upto 90% energy substitution by biogas. Operating on dual fuel principle they use biogas as the main fuel with almost 7 to 10% diesel for initiating and sustaining combustion. R&D efforts to achieve 100% diesel substtution by biogas without loss of power and efficiency are in progress.

Combustion studies using high speed cinematography are in progress to get basic combustion data pertaining to alternate renewable fuels. This would enable incorporation of a new design modifications in the engines to achieve better performance with these fuels. Laboratory trails followed by field test and material compatibility data are being collected with each of these fuels with a number of short term and long term project applications in mind.

Future work in this area includes field tests to assess engine compatibility and to evaluate road performance of vehicles with various synthetic fuels and their blends. Studies on the utilisation of these fuels for better performance and economy, however, will be continued.

Testing and Standardisation

Standard test facility has been set up to evaluate the performance of the flat plate and concentrating collectors. Extensive facilities are available for characterisation of solar cells and wide range of studies on the thin layers constituting it. Absorptance of selective coatings can be measured in the entire range of solar spectrum and can be extended upto 10 microns. Two methods have been developed to measure the emissivity of these coatings at fixed temperatures. A solar simulator has been fabricated and is being used to study the performance of selective coatings in a flat plate configuration of size 50 x 50 cm.

Teaching & Education Programme

A two years post graduate programme leading to Masters degree in the Energy Studies has been started by the Centre from 1980. The centre also offers (beginning July 1981) a one year programme leading to a certificate of the United Nations University Fellowship in the field of renewable energy sources. The special emphasis on solar, wind and biogas energy with technological and socio-economic basis for renewable energy technologies for developing countries.

The centre also undertakes R&D projects sponsored by the industry and other organisations. Collaborative work with other research institutions is also encouraged and supported partially. The Centre has a collaborative research programme in the field of solar energy with Centre National de la Recherche Scientifique, France. Some of the work of Laser Induced Fusion and M.H.D. Power Generation is supported by National Science Foundation, U.S.A. and some work related to bio-conversion is carried out in collaboration with the Swiss Federal Institute of Technology, Zurich.

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During the last ten years, work has been in progres on solar cells. Main thrust is on the development of CdS solar cells which is potentially a low cost device. Aim of the research in this field is to further reduce the cost of CdS solar cells by using simpler technology to enable utilisation of such device as a cost effective alternate source of energy.

Major Achievements

CdS solar cell is basically a semiconductor p-n junction of n-type CdS and p-type Cu_2S. Three methods, namely, (i) ceramic pellets, (ii) spray deposition, and (iii) thin film technique have been used to fabricate the cells in the laboratory.

Ceramic CdS cells of 3-4% efficiencies have been developed. This involves formation of CdS substrate by pressing CdS power to form tablet and sintering the same at a temperature of 700-800°C in an atmosphere of N_2 and H_2 mixture. After proper lapping and etching of CdS tablet, thus formed, one side of it is nickel or indium electroplated so as to form a back ohmic contact. Cu_2S is formed on the other side by electro-diffusion technique from $CuSO_4$ solution. Junction formation is finally realised by a short heat treatment in air. Performance of these cells can be further improved by electroplating a thin layer of copper (100-150A) on Cu_2S surface followed by a short heat treatment in air. Spray technique involves spraying a solution of $CdCl_2$ and Thiourea on hot conducting (SnO_2 coated) glass substrate. Some preliminary results were obtained but the process is not being continued for the present. For fabrication of CdS solar cells by vacuum-deposition technique CdS vas deposited on hot Molybdenum substrate in a vacuum of 10^{-5} torr and Cu_2S layer formed by dipping method. 3-4% efficiency cells were obtained with these cells but some alternative was sought so as to replace high cost Molybdenum by less expensive substrate.

The work described so far is a part of the project on "Opto-Electronic Devices" sponsored by U.G.C. In addition to this, there has been a technical collaboration with the 'Institute Fur Physikalische Elecktronik' and Stutgart University, West Germany.

On-Going Projects

Development of low cost thin film CdS solar cells on glass substrate is the main scheme of work being carried out at present in a project sponsored by Tata Energy Research Institute. It is well known that cost of back contact, front contact and encapsulation tend to make the cells expensive. Indigenous methods are being developed to reduce all these costs to a large extent. instead of silver on glass and back contact (as used by German workers), back ohmic layer is being obtained on conducting SnO_2 layer: formed initially on glass substrate by the chemical vapour depostion process. The CdS layer formed by vacuum deposition, is annealed in a reducing atmosphere of nitrogen and hydrogen mixture. Cu_2S layer is next formed on CdS by dipping method. The front contact from Cu_2S layer is formed by nickel plated copper grid. Without using conventional photo-lithographic technique, which happens to be an expensive one, a much simpler and less expensive technology has been developed for grid formation. By this method grids having 17 lines/cm and transparency of about 70% have been developed. Cells of area upto 6 cm^2 have been obtained by the method having efficiencies of 4-5% with J_{SC} = 20-25 ma/cm^2, V_{OC} 400-500 mv and FF = 0.5-0.6. The main effort is now concentrated on encapsulation and panel construction although efforts are still being continued to improve the open circuit voltage and the fill factor. These and the development of large area cells forms part of the next phase of the project.

Laboratory & Test Facilities

Following facilities for the fabrication of CdS solar cell with different technique are available:

1. Tube furnace - controlled upto 1000°C, with the arrangement of different gas-atmosphere.

2. Assorted furnace and ovens and vacuum pumps and desicators.
3. Gas Cylinders - for N_2, H_2, O_2, CO_2.
4. Spray gun, with air compressor.
5. (a) Vacuum coating unit - 18" - with source and substrate heating facilities.
   (b) Hind Hi - VaC - 12" - coating unit.
   (c) Edward - 8" - coating unit.
   (d) Hind Hi - VaC - Vacuum pump - assembly to raise vacuum upto 10^{-6} torr.
6. Laser - He - Ne - Laser - three (ECIL - two and Siemens - one).
7. Spectrophotometer.
8. Lux meter.
9. Dark room with optical bench.
10. Light sources - Ne - Lamp, Hg - Lamp, Hg - Lamp, Epidiascope, Monochromator and filters.
11. Light microscope - (i) Transmission type upto 1000 x, (ii) reflection type upto 1600 x.
12. Photomultiplier.
13. Clean-room with clean chamber
14. Small chemical laboratory
15. AC voltage stabiliser - 5 KVA
16. Magnet with stabilised D.C. power supply upto 20,000 Gauss.
17. Precision balance and assorted digital meters, nano ammeters, solar water.
18. CRO - one - 50MC/S, two - 15 MC/S.

Future Programme

As already mentioned, cells of 6 cm^2 and efficiencies of 4-5% have been achieved. At present panels are being made out of these cells. For worthwhile research work, further investigations should be directed in three major areas, namely, (a) improvement of performance as mentioned above, (b) increase in area of the cell, and (c) optimization of panel performance. Apart from this, some auxiliary work like development of good solar cell grade indigenous CdS power, material other than CdS and theoretical investigations are being planned during the next three years.

List of Publications

1. Some results on the fabrication of CdS thin film solar cells - D. Mukherjee and Others, NSEC, Bombay, 13-15 Dec, 1979. 349-356.

2. Some studies on CdS thin film solar cells, B. Ghosh and others, Symposium on Photo-physics and Photochemistry, Dept. of Chemistry, Jadavpur University, 4 June, 1980.

3. Some studies on fabrication of cheap CdS solar cells - B. Ghosh and others, Symposium on Solar Photo-conversion Devices and their Application, Jadavpur University, 29 November, 1980.

4. Analytical studies on the performances of CdS thin film solar cells on glass substrates - B. Ghosh and others, Symposium on Photoconversion Devices and their applications, Jadavpur Unversity, 29 Nov., 1980.

5. Effect of shadow on solar cell panels - M.K. Mukherjee and others - Symposium on Solar Energy (Rural and Industrial Appliations), Material Science Centre, IIT, Kharagpur, 7 March, 1981.

Communicated by: Prof. S. Deb. Faculty of Engg. & Technology, Dpt. of Electronics & Tele-Communication Engg., Jadavpur University, Calcutta 700 032.

MADURAI KAMARAJ UNIVERSITY

School of Biological Sciences

Madurai

Madurai Kamaraj University has established a separate School of Energy for Natural Resources and Enviorement from the beginning of the academic year 1980-81. This school will exclusively devote research and development in all aspects of energy related problems as whole covering solar, nuclear and hydroelectric sources.

In addition the School will be concerned with the training of skilled manpower at under-graduate and post-graduate level through formal teaching and training.

National Biomass Centre

With the support of the Department of Science and Technology, a National Biomass Centre has been established in the University under the auspices of the School of Biological Scinces. This is one of the two national centres established recently by the Government of India. This centre will focus its attention on the production of biomass for fuel in the semi-arid regions of South India. Fuelwood species that are most suited for massive cultivation in the marginal lands will be selected after extensive field trails for the different agroclimatic conditions.

In addition, the Centre will be immedately attending to the introduction and adaptation of Guayule, for its rubber yield in the southern states. Other major research undetakings of this Centre would be on the selection and propagation of Cassava, extensive cultivation for use as feedstock for fermentation in Industry. Extension work related to biomass production and utilisation will be part of the functions of the Centre.

Basic Research

Photosynthetic basis of plant productivity with special reference to fuel woodtree species and other biomass producing systems is being evaluated at the basic research level by the plant physiology group, in the School of Biological Sciences. Efforts are underway in determining:

1. Relative light harvest efficiency of chloroplast membranes.
2. Type of carbon fixation pathways involved.
3. Drought and saline stress effect on photosynthetic process and on the development of chloroplasts.

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MOTILAL NEHRU REGIONAL ENGINEERING COLLEGE

Allahabad

The research activities in the field of solar energy utilisation started during 1966 by developing a simple flat-plate solar collector for absorption type of solar coolers., Interest later spread to other areas like cooling of industrial building, fresnel lenses, water lenses, parabolic collectors, compound parabolic concentractors, water pumping, drying of farm produce, and open and indoor cooking.

Solar Refrigeration

In the field of solar refrigeration, a doctoral thesis (completed in January 1981) dealt with desiccant calcium chloride and water. It predicts that it is possible to operate the refrigeration-unit at a lower working temperature, with slightly higher performance than the widely used, though expensive, water-lithium bromide pair. The investigator has designed and fabricated a 0.18 ton refrigerating unit working on $CaCl_2$ water pair. The bubble pump in a thermally operated absorption unit, was tested to ascertain the relative circulation. Data required for the design of such units was developed and expressed in the form of empirical equation. The satisfactory performance of the bubble pump unit paved the way to experiment on the absorption refrigeration unit. Within the perview of the operating conditions, it was found that the system delivered refrigeration 9 to 15°C when heat for its operation was supplied at a temperature of 70 to 77°C. The actual coefficient of performance of the unit was found to be around 0.5, which falls within the range of the generally quoted values for the performance of ammonia-water and water-lithium bromide units. It has been concluded that water-$CaCl_2$ is a less expensive and acceptable pair in an absorption unit, operating on thermal energy available from flat plate solar collectors.

Solar Cooling

Design, technical feasibility, performance and economic factors pertaining to solar cooling of industrial building has been studied. The

effectivenes of continuous roof sprays as means of reducing transmitted solar energy and thereby maintaining comfort conditions inside the industrial buildings with corrugated asbestos and galvanised iron roofs was investigated. This study shows that the inner temperature is reduced by about 15°C at noon time. The effect of lime wash, lamp black, and aluminium paint coatings on the roof and interior temperature was noted.

Fresnel Lenses & Solar Collectors

For manufacturing large aperture spherical and cylindrical fresnel lenses, the merits and demerits of machining, moulding and embossing processes were investigated. A special lathe attachment for the manufacture of steel dies for fresnel lenses was designed. The functional relationship between the radius and step angle depended on the focal length and refractive coefficient of the material of the lens and was first determined. The attachment was adjusted in the beginning to provide the above functional relationship.

Water lenses and parabolic collectors were also analysed and tested. Analytical expressions for predicting fluid and tube temperature of an uncovered Winston collectors were developed.

A depth reduction technique for compound parabolic concentrator (CPC) has been developed. This includes a series combination of two CPC's one filled with a material of refractive index more than that in first stage CPC. By this technique it is observed that for the same aperture and concentration ratios, the collecting surface area is substantially reduced resulting in 50 to 60% depth reduction by a two stage collector as compared to a single CPC. For the reasons of absorption and refraction of rays it is concluded that more than two stage collectors have only limited advantages. A critical concentration ratio is defined in terms of refractive indeces ratio, number of stages the total overall concentration and entrance aperture of the CPC.

The optimum receiver geometry for linear fresnel lens has been investigated for process industries which has the advantage of simple

fabrication technique and commonly available materials required without much skill. The receiver is fabricated of two G.I. pipes with a slot cut along the length of pipes. This forms a black body eccentric annular cylindrical receiver.

On-going Projects

Two reports of investigations pertaining to the design and development of a solar cooker of indoor cooking have been submitted to Appropriate Technology Development Association. Three conceptual designs of solar cooking systems suitable for indoor cooking have been outlined. One of the three suggested designs uses solar collectors to heat oil which in turn is circulated through a solar oven. Mathematical model has been developed and also included in the description of a manually operated closed loop oil circulator that has been designed, fabricated and tested with water. The circulator uses the energy of the compressed air in one tank for lifting the fluid from another tank. A critical difference in level is maintained between the two tanks, one completely filled with fluid and the other being empty except for air. Further work is in progress.

A review on the application of solar energy for food drying is made and an air heater and dryer units are designed for the same. Fabrication is progressing and the thermal analysis will be carried out for such a system.

Work on the design of a 2-ton $CaCl_2$ water absorption cycle is also in progress.

Laboratory Facilities

The solar energy laboratory of the mechanical engineering department is equipped with a pyranometer and other measuring devices for conducting experiments. Computer facilities are also available in the campus for theoretical studies and data analysis.

Educational Programmes

The department offers doctoral programme in the solar energy utilisation and design of windmill systems. It also offers courses in solar energy utilisation

and wind energy system at the undergraduate and post-graduate level.

List of Publications

1. A study on absorption refrigeration system using flat plate collectors by K.V. Mallan. Ph.D. Thesis, Allahabad University, Jan. 1981.

2. Feasibility of water calcium chloride absorption cooling with flat plate solar collectors by K.V. Mallan and B.K. Gupta. All India Seminar on Solar Energy, Kanpur, 1-13, January 1981.

3. Absorption cooling cycles for solar energy utilisation by K.V. Mallan and B.K. Gupta. Symposium on Renewable Sources of Energy, National Academy of Sciences, India, Oct. 1980.

4. Design and development of a bubble pump by N.M. Malasi. M.E. Thesis, Mech. Engg. Deptt., MNREC, Allahabad, 1980.

5. Use of alcohols in petrol engines by B.K. Gupta and Ajeet Singh. Paper V-31, Engineering the Future for the Benefit of Mankind, National Seminar, Inst. of Engineers, Calcutta, Feb. 1980.

6. Review on application of solar drying for drying food stuff by K.V. Mallan and others. Solar Energy: International Progress Pergamon Press, New York, 1980.

7. Modelling of solar drying by Ravindra Kumar. Solar Cooling and Dehumidifying Conf. (Solar/80) Caracas, Venezuela, 1980.

8. Performance of a novel cylindrical receiver by Ravindra Kumar. Solar Energy Symp., Osmania University, 1980.

9. Design and development of solar cooker for indoor cooking by B.K. Gupta. Report No. 1 and 2, Mech. Engg. Deptt., MNREC College, Allahabad 1980.

Communicated by: Dr. R.K. Bharadwaj, Reader in Mech. Engg. Deptt., Motilal Nehru Regional Engineering College, Allahabad.

PSG COLLEGE OF TECHNOLOGY

Coimbatore

The work on biogas was started at the PSG college of Technology in 1976 in a small way using 200 lit oil drums and running a 1.5 kW petrol engine generator set. Later, a 5000 litres capacity plant was constructed. Tests were conducted by running the diesel engine as a dual fuel engine with upto 80% heat in-take in terms of biogas and 20% diesel. The combustion characteristics, efficiency of operation and vibration characteristics of the diesel engine running on dual fuel were studied and were presented at the National I.C. Engine Conferences based on the results conducted on a 10 hp, 1500 rpm diesel engine; 5 hp, 1500 rpm diesel engine and a 1.5 kW petrol engine generator set. A gobar gas carburettor for the constant speed engine has also been developed. Investigation on the continued use of gobar gas on the engine life is continung. Also the use of leaves, grass and agricultural wastes for biogas generation is being investigated.

A plant, to use human waste produced by the hostel inmates, for production of biogas has been constructed and results are under observation. The total cost of these works was Rs.50,000/-. Facilities of the Heat Power Laboratory of the college was used for the experiments.

Experiments on compression of gobar gas into cylinders is being planned. This will facilitate the use of biogas for transportation purposes.

Producer Gas Plant

A charcoal gas producer to power a 3 kW engine has been fabricated and is under trial for the last one year. A mixture of coal and charcoal is used in the gas producer. The work was done during 1980 with a cost of Rs. 2,500/-.

Solar Energy

Work on solar energy was started at this college in 1977. A solar cooker and a solar water heater were fabricated and these were exhibited at the

International Solar Energy Conference at Delhi during 1978. Subsequently a 2 m^2, 200 litre capacity water heater was fabricated using local skill and local material. At present, work is in progress to integrate the solar water heater in the building itself. Also, solar panels enclosed in brick work and the use of ferro-cement tanks are under investigation.

A solar still of 1 m capacity is under observation. A solar assisted 1 ton absorption refrigerator (ammonia-water) has also been fabricated and is under test.

List of Technical (Student Treatise) Reports

1. Design and fabrication of a producer gas plant, 1979.
2. Conversion of an existing 1 ton vapour compression plant to solar assisted vapour absorption plant, 1980.
3. Investigation in the use of ferro cement plant for solar water heat, 1980.

Communicated by: Dr. C.P. Kothandaraman, Prof. of Mech. Engg., PSG College of Technology, Coimbatore 641 004.

PUNJAB AGRICULTURAL UNIVERSITY

College of Agricultural Engineering

Ludhiana

An active programme for the utilisation of renewable energy resources is under way for about a decade at the College of Agricultural Engineering, Punjab Agricultural University, Ludhiana.

A considerable understanding of solar thermal processes has been developed and a number of useful developments have been taken place to harness solar energy as heat for various purposes. These include design, development and testing of various solar devices using flat plate collectors, linearconcentrators and parabola dish collectors.

The work on design, development and testing of improved chulas (cooking stoves) has also been in progress for a decade. Notable improvements have been achieved in the overall combustion efficiency in these units.

The work on biogas (gobar gas) plant was started five years ago. Considerable success has been achieved in improving the performance of biogas plants in winter. The designs have also been evolved which promise better performance and economics of these units.

The work on biomass or energy agriculture was started about two years back and within a short time, remarkable progress have been achieved in completing a number of projects. These projects have furnished important data about the availability of biomass and has provided guidelines for further work.

1. Solar Energy Utilisation

Solar energy research work at PAU started, during 1970. The work is being carried out largely according to the objectives of four research projects:

1. Utilisation of solar energy for creation of optimum environment for animal and plant production systems.

Objectives: The basic objective is to design, develop and evaluate various solar devices for agricultural, domestic and industrial applications as well as to create moderate thermal environment in farm building by using natural resources.

2. Design and Development of solar energy collector units for production of high pressure steam and vapours for applications, as an alternative source of energy.

Objectives: The main objective is the design, development and performance evaluation of a stationary compound wedge collector as a producer of steam or high pressure vapours, and to use the collector array for operating solar thermal machanical power units.

3. Natural heating and cooling of building in Northern India.

Objectives: The main objectives is to achieve moderately comfortable thermal environment throughout the year in residential houses using sub-soil water for winter heating and natural evaporation and night sky radiation for summer cooling.

4. A coordinated research programme on operational research in solar energy utilisation in agriculture.

Objectives: The main objective is to design, instal and evaluate performance of solar crop dryers in the laboratory as well as in the field.

Notable achievements have been made in the design, development of cheap and efficient solar devices such as solar water heaters, air heaters, solar ovens, solar stills, vegetable and fruit dehydrators, crop dryers, etc. New developments have been taken place in the design and development of stationary concentrators using curved and flat surfaces which enable collection of solar energy at temperatures of about 150°C.

New designs of Rankine engines have been evolved to work on high pressure vapours for production of mechanical power. Simple techniques have been developed for the fabrication of parabola dish collectors. Some useful work has been initiated and is being carried on natural envioremental control of residences and farm buildings. New ideas both in the design and in the use of materials have been used in the design and development of most of the solar energy systems.

Currently research include design and development of solar crop dryers, vegetable and fruit dryers, collector developed for high pressure vapour generation/steam generation, design and development of ovens and parabola dish cookers and vapour prime movers. Some studies are being conducted by using aluminised myler as a reflecting surface.

1.1 Paddy/Oilseed Dryer

The design of one ton crop dryer for paddy and oilseed crops has been completed. The air heaters for this dryer has been fabricated and they will be installed shortly and serve as roof under which the drying bin and air circulating fan will be installed. A one-fourth scale model of such a unit has already been installed. Preliminary testing has been carried out. The air heater (4.5 m x 1.5 m) consists of a flat plate collector of shallow rectangular cross-section (4 cm deep) designed to collect solar energy at an efficiency of about 50% at a temperature rise of 15°C to 20°C. Preliminary trials of the system have been completed and solar energy collection efficiency of about 50% has been obtained for a temperature rise of 15°C. Four of these air heater units provide required collector area for one ton dryer. These air heater units can be fabricated at a central place, transported to the site and assembled there to install crop dryers.

1.2 Multi-rack natural convection dryer

This device is a significantly improved version of conventional solar cabinet dryer. The main idea used for performance improvement is to bring the drying air in contact with the product several times as compared to one contact

as in the cabinet dryers. The aperture area inclined at 45°C is about 6 m^2. Fourteen horizontal trays are arranged in two columns each having seven rows one above the other. Sliced vegetables or fruits are stacked in trays kept at several levels one above the other while the solar energy heats the inside air and inside surface of the dryer. The hot air moves up through trays containing vegetables etc., by natural convection removing moisture as it moves up. Dampers at the top exit help to control the air movement through the dryer. Extensive trials of drying various vegetables have been carried out. it has been found that the capacity of this dryer is nearly double compared with a same sized cabinet dryer (i.e. same aperture).

1.3 Plastic Air-Heater-cum-Vegetable Dryer

With a view to reduce the cost of air heater equipment as well as to study the use of plastic materials available in the market, an air heater consisting of black polythene sheets as absorber, a transparent polythene film as glazing and air entrapped in plastic sheets as insulation at the bottom, has been fabricated to supply hot air to a drying chamber in which three trays are kept one above the other. The vegetables and fruits to be dried can be kept in the trays. Preliminary performance has shown that satisfactory drying of products can be carried out in two days. Since the product to be dried is not exposed to direct sunshine, the colour of leafy vegetables have been found to be quite natural compared with the yellowish green obtained in the cabinet dryer.

1.4 Sliding Vane Vapour Engine

There remained the problem of leakage of vapour in the reciprocating engine. Accordingly, a new engine of rotary type, operating on Freon-11 vapours was designed, developed and tested. The engine consists of cylindrical stator and an eccentrically mounted cylindrical rotor. Three sliding vanes have been provided in the rotor. This design affords selection of desirable vapour cut-off and expansion ratio. This is accomplished by providing axial entry to port-cum-valve system. Opening and closing of the ports is accomplished through the commutation between the sliding vanes and the ports. Engine frame

is of 15 cm long and is rated to develop 1 H.P. while operating with Freon-11 vapours at a pressure of about 14 atmospheres. The engine was tested with compressed air and was found to develop 0.42 H.P. while operating with compressed air at 7 atmosphere pressure.

1.5 Parabola Dish Solar Cooker

A parabolic dish solar collector has been designed, fabricated and tested in continuation of the previous work. Recently a new reflecting material i.e. Aluminized Myler has become available and this material has been used in the fabrication of this cooker. The reflecting dish has an outer diameter of 130 cm and inner diameter 25 cm. The dish consists of 22 appropriately shaped GI sheet sectors on which aluminized myler has been pasted using Levicol. Preliminary performance trials have been carried out. The cooker is capable of boiling 1 litre of water in about 12 minutes on a typical sunny day. An automatic on-off tracking system has been incorporated in the cooker. The dish is mounted in the north south direction and its altitude is adjusted occasionally, according to the altitude of the sun in the sky.

In a project sponsored by the Department of Science and Technology, Govt. of India, work is continuing on the design, development and performance evaluation of compound wedge collectors using plain mirrors as reflectors. Detailed manufacturing drawing were prepared for fabrication by outside agencies.

Two units fabricated by BHEL have been received and are being fitted together for evaluation. A local manufacturer has been asked for fabricating two more units. The collector has an aperture of 4.8 sq. m. It is designed to produce process steam at pressure of 4 to 5 atmospheres or to produce high pressure organic vapours. The purpose of this project is to study the thermal as well as economic performance of this collector to produce process steam.

1.6 Solar Energy Storage

Work has also started to evaluate the rock and storage system for storage of solar energy for a period of 4 to 8 hours, so that the work of crop

drying could be carried out for a period of 12 hours a day. A small size pebble storage has been fabricated and is being evaluated.

1.7 TERI House

A two bedroom house has been constructed to study the performance of a natural heating and cooling system. In the new system, the roof has been modified by passing a grid of pipes through it so that it can work as a heat exchanger. In winter, underground water at 28°C will be passed through roof slab, warming it so as to have radiant heating and in summer roof will be used as an open pond to cool water which will cool the roof slab. The cool slab thus will keep the house cool throughout the day. Observations of its performance have started from April 1981.

2. Fuel Conservation in Domestic Combustion

A survey conducted in the villages of Punjab revealed that about 95% of energy is used in the kitchen. Hence energy conservation in the domestic combustion is of utmost importance. Keeping this point in mind some design-improvements have been made in the existing designs of chulas (cooking stoves).

2.1 Chula with Fire-grates

The most popular design of a rural chula consists of a semi-circular combustion space. The fuel is burnt here and the air for combustion of fuel is supplied from the surroundings. Due to this reason the fuel at the outskirts and on the top side gets fresh air for combustion, while the fuel below or near the walls of the chula gets insufficient quantity of air. The fuel is disturbed from time to time for combustion. The ash and unburnt fuel collects in the semi-circular space and has to be removed as and when required.

In order to complete the combustion of the fuel easily the design of the common chula has been improved by providing fire-grates at the place of combustion. The air enters from below and passes through the burning fuel. In

this manner the rate of combustion is increased to double as compared to that of common chula.

2.2 Chula with Water Jacket

In common chula lot of heat is wasted through the walls during the combustion of the fuel. A water jacket around the walls win back some of this waste heat and conserves energy. Hence, this chula gives an indirect saving in fuel consumption of the order of 9% by heating the water in the water-jacket. The radiation losses of this chula could be further reduced by insulating its water jacket. The cheapest method of doing this is to use brick-clay insulation around all the sides and at the bottom of the chula.

2.3 Chula with Fire-grates & Water-jacket

The design of the above chula has been modified by providing fire-grates in the semicircular space for providing the air supply to the fuel from below and hence improving the combustion processes. There is no water-jacket at the place of fire-grates and hence the size of the water jacket has been reduced.

2.4 Smokeless Chula

The design of the chula has been modified by providing a chimney for releasing the burnt gases. This design modification does not allow any smoke to come in the kitchen. The other modification in the design consists of water jacketing the walls of the chula and a part of the chimney. This design improvement helps in utilising the heat losses through the walls of the chula and the exhaust gases with an increase of efficiency of about 11%

The ongoing projects include the development of a multi-fuel water heater and multi-fuel boiler. The water heater is being designed to burn different types of agrowastes and wood as fuel. Some improvements in the combustion of fuel are under trial to increase the thermal efficiency of the boilers.

The future programme includes the development of an agro-waste water heater. This water heater will be capable of burning almost all types of agro-wastes such as leaves, twigs, bushes, straw, even bundles of thin sticks or shrubs upto a diameter of about 30 cm. The other development consists of the use of agro-wastes as fuel in the industrial boilers. These boilers produce steam for processing industry and power plants.

3. Biogas Technology

The Department of Civil Engineering at PAU has been working on biogas technology since 1975. The work is primarily to evolve suitable designs of small and medium biogas plants which should be economical in cost, easy and trouble free to operate and durable enough to assure farmers good return on their limited investment.

Field models of KVIC and Chinese/Janata plants were constructed. Four reactors of KVIC type put up at PAU were tested for their performance. This gas yield has been found to be about 1.8 to 2 cft/kg. of cowdung during summer and 0.8 cft/kg of dung during winter.

To improve the gas yield during winter, composting technology was used. This comprisedof constructing 3' wide x 3' deep pit all around the biogas reactor filling it with alternate layers of straw and cowdung. The compost pit enabled the reactor temperature to be raised from 17°C to 25°C, thereby increasing the yield to 60-70% of that obtained from uncomposed reactor.

The Chinese/Janata model constructed at PAU gave a gas yield of 1 to 1.2 cft/kg of cowdung. Thus the comparative study shows that KVIC model produced twice as much gas. The chinese/Janata model showed severe leakage problems which could be ascribed to diffusion of gases through plastered wall and dome, poor hydrodynamic circulation caused by dead slurry pocket and air pocket.

To improve the performance of the Chinese/Janata model plant various measures are being tested. These include use of membrane technology mild

steel sheet roofing, and sealant method for reducing diffusion from junction walls. Further, small scale model study using mobile oil pumps and fitted with suitable baffle walls has been made which has shown that it is possible to obtain a gas yield of above 2 cft. gas/kg cattle dung.

The inter seasonal variation in the gas yield showed that the gas production during winter falls to about 40% of that in summer. However, by making use of the composting technology, it is possible to increase the production to a level of 70%.

The drying beds method of handling slurry from the digester has been found to be very successful. Besides reducing the moisture contents of the digested slurry to 60% in 4-5 days, the method does not result in any appreciable loss of nitrogen.

To increase the temperature of biogas reactor for attaining higher yield, the compositing method has been found to be much superior to the solar water heater as with the latter, the rise in temperature of biogas reactor was only 1/2°C.

Certain models have been developed for fermentation of slurry in stages to reduce the contents of CO_2 and increase the percentage of methane. Preliminary observations has shown very encouraging results. It is estimated that calorific valves can be increased upto 30% by stage fermentation, with increase in cost not exceeding 10% to 15%.

4. Energy Agriculture

The concept of energy agriculture was developed on the basis of studies carried out from 1976 onwards. Following inferences were drawn from the above studies:

1. The replacement of traditional technology with improved technology in production agriculture and agro-processing required considerable inputs of commercial energy in the form of machinery and equipment, mechanical power

and chemicals (fertilizers, plant protection material, etc.). The commercial energy input for shifting from a no mechanisation, no fertilizer, no irrigation situation to partial mechanisation, use of chemical fertilizers and irrigated agriculture situation, under Indian conditions, ranged from 10,000 to 20,000 MJ per crop hectre.

2. The above described shift in the technology of production agriculture resulted in at least three-fold increase in the biological harvest.

3. The ratio between the energy value of the biological harvest and the commercial energy input under conditions of improved technology was of the order of 20:1 or higher.

4. The increase in biological harvest tended to render some crop residues surplus to their conventional use as feed, bedding material and fuel. This was particularly true of those crop residues which could not be used as fuel in the kitchen. Paddy straw in the North Western region, comprising Punjab, Haryana and Western Uttar Pradesh, was the most conspicuous example of surplus crop residues.

5. It appeared to be feasible to convert the surplus crop residue into usable energy to meet part or the total requirement of commercial energy of production agriculture.

6. Farm processing of agricultural produce consumed small quantities of commercial energy. Industrial processing of agricultural produce, however, consumed large amounts of commercial energy without adding to the intrinsic energy value of the product.

As a result of the above studies, the concept of generating adequate biomass surplus out of production agriculture to meet the total or most of the commercial energy needs of production agriculture and agricultural processing was considered feasible. This concept is called "Energy Agriculture". Various research proposals were drawn under sponsorship from different agencies to develop and test the concept between 1977 and 1980.

4.1 Energy Balance & Utilisation

Summary

1. The energy requirements for production agriculture on tractor operated farms are only marginally higher than the energy requirements on bullock operated farms.

2. The use of commercial fuels for cooking in rural households is very limited. The farm families depend mostly on fuel wood, crop residues, particularly from wood plants like arhar and dhaincha and animal dung cakes to meet the energy requirements for cooking.

3. Most of the crop residues are almost fully utilised, as fuel or fodder or both, except for paddy straw, most of which is burnt in the field.

4. The farmers are fully aware of the value of animal wastes as manure but they still use about 71% of the animal waste as fuel. A community type gobar gas plant is likely to meet the household energy requirements of a large percentage of village community and at the same time provide digested slurry for use as fertilizer. Such an approach would, however, pose many technical and organisational problems.

5. The energy potential of agricultural wastes generated per hectare of cultivated land in the survey sample was 22.6×10^6 kcal. Theoretically, the energy requirements of the rural community in the situation studied (inclusive of production agriculture, household activities and animal husbandry) can be met from the energy available from agricultural wastes.

6. The energy potential or residues of major crops grown in Punjab is about 73.40×10^{12}kcal. The crop residues are burnt in the kitchen at a very low efficiency. Improved devices for burning such material in the kitchen and the organised combustion of crop residues to produce steam and power could give much higher efficiency of utilisation. The energy potential of paddy straw alone burnt for disposal, is 24.9×10^{12} kcal. If properly converted into energy, it can provide a substantial relief from energy constraints on lift irrigation in the State.

7. Thermal conversion of paddy straw to produce steam/electric power appears to be an attractive and practical method of utilising this material which otherwise is almost completely wasted. Appropriate modifications in the current design of boiler furnaces will allow the use of straw alone or in mixture with coal as a commercial fuel.

8. The shortage of firewood and commercial kitchen fuels like L.P. gas, kerosene, etc. and the serious shortage of diesel fuel require that research efforts should be intensified to develop practical technology for the conversion of straw and other biomaterials into clean gaseous and liquid fuel through selected pathways offerd by thermo-chemical processes.

4.2 Sugarcane as an Energy Crop for Punjab

Summary

1. Improvement in the machinery and incorporation of energy conservation practices can reduce the energy consumption of old sugarmills to a level that their dependance on external energy inputs is completely eliminated and upto 20% bagasse becomes surplus.

2. Integration of production of alcohol (from molasses) with improved sugar mill operation will allow the use of surplus bagasse for alcohol production, thereby reducing the external energy input (usually in the form of urea). Such arrangement will also minimise the molasses and fuel transport costs.

3. In view of the current relative prices of sugar and alcohol and the shortage of edible sugar, it is not practicable to grow sugarcane for alcohol production.

4. Feasibility report on the utilisation of rice straw for power production in Punjab has been prepared.

5. On-going Projects

Six major research projects were taken up in 1980. These are briefly summarized below:-

1. Survey of Energy Use Pattern in Five Village of Northern India

Objectives

To generate information on (1) amount of energy consumed in (a) households, (b) production agriculture, and (c) post-harvest technology; (2) relative importance of different source of energy in the above three areas of utilisation; (3) efficiency of utilisation of energy in various application in agriculture.

To determine the response of energy use pattern to variations in agricultural technology, social and economic factors, and relative availability of different energy resources.

2. Biomass Resource Survey

Objectives

To estimate the availability of biomass resources in the five districts in which the energy use pattern survey would be conducted and to assess the biomass resource potential in each of the five districts. To identify barriers preventing (a) increase in biomass production, (b) efficient and wider utilisation of biomass as an energy source.

The work has started in November 1980, in the District of Ludhiana. These studies will be extended to the District of Karnal in 1981 and will be completed in all the five districts by early 1982.

3. Study of Biomass Characteristics

Objectives:

To study biomass characteristics having a bearing on the pre-conversion technology and pre-conversion reaction.

These studies were initiated in October 1980 and include determination of calorific values, proximate analysis, ultimate analysis, bulk density, angle of respose and flamability of 13 different cop residues; analysis of the ash obtained from the combustion of these residues and analysis of the gases produced during combustion, gasification and pyrolysis of the same residue. Thermo-gravimetry studies will be added in 1981.

4. Pre-conversion handling & processing of biomass

Objectives:

Development of a viable technology for the harvesting, handling, drying size reduction, densification, transport and storage of agricultural residuces.

The work at present, has been limited to the residues of rice crop, maize, arhar and dhaincha. The cost of collection, densification, transport, handling and storage of rice straw has been worked out. The studies are being extended to other residues.

5. Biomass Conversion

Objectives:

Study on combustion of biomass to optimise operational parameters and obtain higher combustion efficiences consistent with minimal environmental pollution and the requirements of different agril applications.

Study of the chemistry and thermo-dynamics of gasification, pyrolysis and liquifaction of biomaterials. Optimisation of the operating parameters for thermochemical conversion of biomass. Determination of the properties of the products of thermochemical conversion product, improvement for increasing clean fuel yields and characterisation of the residues.

Studies on acid hydrolysis of cellulosic biomass. Optimisation of operational parameters to increase cellulose to sugar conversion.

Studies on enzymatic fermentation of cellulose for conversion into sugars.

Study of the chemistry and thermo-dynamics of cellulose-sugar conversion. Study of residue properties.

Studies on mechanical/chemical extraction of hydrocarbons from biomass. Product improvement. Study of residue characteristics.

At present, the work is in progress only on gasification. An experimental gasifier (updraft type) was designed and fabricated. The prototype is being utilised to optimise process process parameters for gasification of low ash residues. The design of a moving grate experimental furnace for the combustion of agricultural residues has been completed.

6. Energy Management & Conservation in Agriculture

Objectives:

Design and development of equipment and practices for efficient use of energy for production agriculture and post-harvest technology.

Studies have been initiated in November 1980 to identify the causes for low efficiency of energy use in agricultural sector. Complete sets of five different makes of the components of small H.P. diesel engines manufactured in Punjab State have been subjected to complete dimensional and material analysis in the laboratories of the Mechanical Engineering Research and Development Organisation of CSIR, Ludhiana. The information generated as a result of above trial is being analysed to identify the causes for high specific fuel consumption of the locally manufactured engines.

6. Future Programme Envisaged

A proposal to convert the present programme into a Centre of Advanced Studies on Energy in Agriculture is under the consideration of the Indian Council of Agricultural Research. Subject to the availability of financial support, the technical pogramme will be strengthened and extended to cover the

following areas:

a) Studies on energy requirements and energy use pattern in the rural sector.

b) Regionwise study of the biomass resource availability and potential.

c) Physical and thermo-chemical characteristics of biomaterials.

d) Pre-conversion technology.

e) Biomass conversion.

f) Improvement of energy use efficiency and application in the rural sector.

g) Residue disposal.

h) Feasibility studies, system modelling and management.

i) Pilot/demonstration projects.

7. List of Publications

1. K.D. Mannan., L.S. Cheema and Rajinder Singh

Design and performance of solar date dryer presented at National Solar Energy Convention - Dec 1980, Annamalai University, Annamalainagar, India.

2. Amrit Lal Jhanji, K.D. Mannan and R.M. Engira

Performance of cylindrical parabolic concentrator with on-off tracking. Presented at National Solar Energy Convention, Dec. 1980. Annamalai University, Annamalainagar, India.

3. K.D. Mannan and R.M. Engira

An improved design of an organic vapour solar engine. Presented at National Solar Energy Convention, Dec. 1980, Annamalai University, Annamalainagar, India.

4. K.S. Salariya and Mangal Singh

Economic evaluation of solar cooking appliance, 18th Annual Convention of the Indian Society of Agricultural Engineers, 1980, Indian Agricultural Research Institute, Delhi., February 1980.

5. K.S. Salariya and Daljit Singh.

Energy technology for the villages. Seminar on agricultural engineering farm-inputs, held at Moga on 5, Sept. 1980. Organised by Punjab Agricultural University & Food Specialists Ltd., Moga.

6. B.S. Pathak and others

Paddy straw - a potential source of enegy in rural Punjab, 18th Annual Convention of the Indian Society of Agricultural Engineers, Indian Agricultural Research Institute, New Delhi, Februay 1980.

7. K.S. Salariya.

Maize cobs as domestic fuel, Proceedings, National Symposium on Recycling of Residues of Agriculture and Industry, Punjab Agricultural University, Ludhiana,27-28 March, 1980.

8. K.S. Salariya and I.K. Garg

Agro-wastes as a domestic fuel, National Symposium of Utilization of Agricultural and Forest Residues, Indian Institute of Chemical Engineers, Chandigarh Regional Centre, Punjab University, Chandigarh 26-28 Sept. 1980.

9. K.S. Salariya.

Unconventional energy sources for domestic combustion, Seminar on the Unconventional Energy Sources, sponsored by Institution of Engineers, India, Guru Nanak Engg. College, Ludhiana, Sept. 1980.

10. K.S. Salariya and S.L. Jindal.

Agricultural wastes as boiler fuels in oil seeds based industries, Symposium on Processing of Oilseeds, Oils, Byproducts and Derived Products; Techno-Economic Aspects of Oil Technologists Association of India, Proceedings Regional Research Laboratory, Hyderabad, 14-15 February 1981.

11. B.S. Pathak and K.S. Salariya.

Heat conserving ring for angithies, Agricultural Engineering Today: Vol 5, No. 1, Jan - Feb 1981; 17-19

12. S.K. Vyas and K.N. Duggal.

Over-view of methane generation of biogas from cattle waste. Journal of Rural Plan, Chandigarh 1980.

13. S.K. Vyas and K.P. Goswami.

Recycling of biomass for biogas and manure. Presented at the Annual Conference of Institute of Engineers, India Sub-Centre, Ludhiana September 1980.

14. B.S. Pathak and others.

Energy balance and utilization of agricultural waste on a farm. Final Report of the project sponsored by Tata Energy Research Institute, 1980.

15. B.S. Pathak and others.

Studies on sugarcane as an energy crop for Punjab.
Final Report of the project sponsored by Tata Energy Research Institute 1980.

16. B.S. Pathak

Rice straw - a potential source of energy for rural sector in Punjab. Paper presented in a National Symposium on Utilization of Agricultural and Forest Residues held at Chandigarh, 26-28 Sept. 1980.

17. B.S. Pathak., A.S. Bining and A.K. Jain.

Relative economics of post-harvest handling and transport of rice straw for power generation. Paper presented at the 18th Annual Convention of the Indian Society of Agril. Engineers held at Karnal, 26-28 February, 1981.

Communicated by: Dr. K.D. Mannan, Prof. of Mech. Engg., Punjab Agricultural University, College of Agicultural Engineering, Ludhiana.

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY

Patiala

Solar energy research was initiated in 1977 when work started on the design and development of a flat plate solar steam cooker. A flat plate collector of dimensions, 1.25 m x 0.8 m with aluminium sheet, serpentine copper tube and two glass covers was designed and fabricated. This design gave boiling water for about $2\frac{1}{2}$ hours in summer months and about one hour in cold months. The performance of this collector was studied in combination with a conventional cooker of 1 litre capacity, and it was found that the system was cooking satisfactorily vegetables, cereals, eggs. mutton etc. The testing of this system was done over a period (about two years) and its efficiency evaluated. The causes of low efficiency have been identified and further work includes improving the efficiency of the collector through the use of better design, viz. honeycomb type. Further, data on solar radiation availability round the year at Patiala has been collected.

A second projet initiated in 1979 was the design and developmet of a heat pipe for solar energy application. The aim was to develop heat pipe that can be used in a flat plate collector. This system has the advantage of avoiding the liquid, which is circulated under large collector plates. Also, the heat pipes can be operated as diodes to cut off the loss of heat from the storage liquid to the atmosphere when the collector plate is at low temperature. A stainless steel heat pipe has been fabricated. Its testing is in progress.

A project "Comfort Conditioning of Middle Class House in India" was initiated in December 1980 sponsored by Tata Energy Research Institute. The first phase of the programme which is an extension of the work done earlier is in progress. It involves heat transfer analysis of the unconditional houses through 'Electric Analogue Method'. The panels of R-C circuits representing house elements are being fabricated. A computer programme based on the numerical solution of unsteady flow heat transfer equation for walls is also being developed. These are to be used for parametric studies involving the thermal behaviour of materials and alternatives methods of construction of buildings using different configurations etc.

Studies on the comprehensive analysis of the technological and socio-economic aspects of bio-conversion plants making indirect use of solar energy are also in progress. Two gobar gas plants of moderate sizes are already in operation. Their efficiency is being evaluated.

Department of Mechanical Engineering of the Institute has a Heat Transfer Laboratory suitable for carrying out research and development programmes in solar energy utilisation.

Recent Publications

1. R.K. Rajput and Gajendra Singh. 'Performance of a Flat Plate Collector for Solar Cooker', Proc. National Solar Energy Convention, 1979.

2. R.K. Rajput and Gajendra Singh. 'Design and Performance Aspects of a Flat Plate Solar Steam Cooker', J. Instn. of Engrs. (India). Interdisciplinary and General Engineering Div., Vol. 61, Oct. 1980 - Feb. 1981.

3. R.K. Rajput and Gajendra Singh. 'Flat Plate Steam Cooker - Its Design, Performance and Efficiency' submitted for presentation in the International Solar Energy Conference to be held in Brington, England on Aug. 23-28, 1981.

4. R.K. Rajput. 'Performance and Analysis of a Flat Plate Solar Steam Cooker, 'M.E. Thesis, Punjabi University, patiala, 1980.

Communicated by: Dr. Gajendra Singh, Prof. & Head, Deptt. of Mech. Engg., Thapar Institute of Engineering & Technology, Patiala 147 001.

UNIVERSITY OF AGRICULTURAL SCIENCES
Department of Agricultural Engineering
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A no-glass flat-plate collector with G.I. corrugated sheet as absorber plate and plywood as insulator is fabricated. The dimension of the collector is, length 305 cms, width 274 cms and depth 10 cms respectively. Black asphalt is painted on the top of the G.I. corrugated sheet for maximum absorbtion of solar radiation. The collector is mounted on M.S. angle iron. The collector is oriented towards the equator at an angle equal to the latitude of the experimental site, Bangalore city, (India) namely 13.0° N. The arrangement of the experiment is such that it is in situ. Parameters such as, temperature of solar heated air, relative humidity, volume of air, static pressure, moisture content of Sorghum seed, germination percentage of seeds, sunshine hours, wind velocity etc., are recorded at an interval of every hour starting from 8.30 a.m. to 4.30 p.m. on the days of the experiment.

Freshly harvested and threshed seed with 24% moisture content or below, is dryed to as low a moisture content as 8.5%. The quantity of seed dryed in each batch is 50 kgs, 100 kgs, 150 kgs, and 200 kgs respectively, at a time. During the experiment all the parameters mentioned above are recorded for each batch.

During the experimental period, the sunshine was varying from 0.8 hours to 10 hours per day. During most of the days the drying is carried out with the solar heated air obtained with intermittent and diffused solar radiation. A maximum increase of 7.5° C of solar heated air to the ambient air temperature has been recorded, when the volume of air passing through the dryer was 41 cum/min. The minimum rise in solar heated air temperature has been observed to be 2° C. The time of drying varied from 2 to 3 days, starting at 8.30 a.m. and ending at 4.30 p.m. each day. It is found that sorghum seed with 24% moisture content could be dryed to 8.5% moisture content. Samples drawn during the experiment and tested for germination ranged between 84 and 92%, which is an acceptable percentage for seed certification.

The ultimate object of the experiment is to see that the farmers buildings with G.I. corrugated sheet will act as a flat-plate collector, when a plywood sheet is nailed at the bottom of the rafters. The farmers could dry not only food grains, but also seeds without incurring additional expenditure for the fabrication of no-glass flat-plate collector, with the above experimental arrangement.

Communicated by : Mr. B. Kempe Gowda, Group Leader & Agricultural Engineer, Main Research Station, The University of Agricultural Sciences, Hebbal, Bangalore 560 024.

UNIVERSITY OF POONA
Department of Chemistry
Pune.

Various solar devices making use of locally available materials have been developed. A brief account of these are given below.

Solar Cookers

Of the different types of solar cookers developed, one is domestic solar cooker having an electroplated brass vessel to accommodate the cooking pot and to reflect additional sunlight, which can cook about 100 g of rice in about 45 minutes with one reflecting mirror. The cost of this cooker is about Rs.100/-. Another type makes use of a low cost earthenware pot instead of the expensive brass vessel and can cook rice in about an hour's time with two mirrors. The cost of this cooker is about Rs.50/-. A third cooker is developed for mass cooking wherein at a time 4-5 pots can be kept. For this purpose, 4-5 big buffed aluminium reflectors are used.

Solar Water Heater

This has a wooden box with a thin (2 mm) aluminium sheet fixed at its bottom on which a zig-zag copper tubing is fixed having an inlet and an outlet. The aluminium sheet and the copper tube are painted black. The box has a top glass cover. Cold water is made to flow at a rate of 1 lit/min from the inlet. The hot water at the outlet comes out at an average temperature of 55 $^{\circ}$C without an external reflector. The output temperature rises to 58 and 61 $^{\circ}$C with one and four reflectors respectively.

Thermal Storage

A solar heat-storage system has been developed making use of the heat given out in the process of crystallisation. Two substances, ammonium acetate and pyrocatechol were used for this purpose. It is found that the material (e.g food) remains warm (at temperature of about 42 $^{\circ}$C) for 5-6 hours after the

container having the food is placed in a pot containing the molten substance.

Solar Distillation

A solar distillation plant having the dimensions of 2 x 0.7 m^2 has been developed. This consists of a tray made of an iron sheet fixed in an iron-angle frame. Clean and transparent glass plates are fixed in the shape of tent on this frame at an angle of 20°. Water is collected in the channels. This unit has an output of 5 lit of distilled water per day, with a maximum rate of distillation of water at about 14 hrs. on a clear-sky day.

Communicated by : Dr. H.J. Arnikar, Prof. Emeritus, Dept. of Chemistry, University of Poona, Ganeshkhind, Pune 411 007.

OTHER ACADEMIC INSTITUTIONS

Gujarat University, Ahmedabad

The Department of Physics is engaged in research on wind energy utilisation and solar energy utilisation.

A vertical axis windmill and wind collector was designed and tested. The first working model was completed during 1976-78. A new design is finalised.

The project on solar energy utilisation has just begun with in-house funds. A system is being designed to use both thermal as well as optimal energy of the solar spectrum, to convert into electricity directly.

Publication

A vertical axis windmill and wind collector by S.D. Verma.
National Solar Energy Convention 1979; 460.

Indian Institute of Management, Ahmedabad

The institute started research work on renewale energy during 1975. The work completed are in the following areas:

1. Economics analysis of biogas systems in India
2. Comparative analysis of biogas systems in India and China
3. Management Information system and control for biogas.
4. A cost-benefit analysis methodology for biogas system.

Presently a project is progressing to etimate the rual energy supply-demand balane and the socio-administrative system of the community size plants in India. The poject is sponsored by the Department of Science and Technology for a period of three years.

Future work envisaged are : (1) A cost benefit analysis manual for renewable energy projects (2) An educational programme for MBA students on rural energy.

Publication

"Biogas and rural energy supply in China" by T.K. Moulik., in "China After Mao" (to be published).

Jawaharlal Nehru University, School of Enviormental Sciences, New Delhi.

In addition to on-going projects in the area of monitoring and control of environmental pollutants, work on three projects in the area of renewable energy utilisation is in progress. One of the projects deals with the socio-economic analysis based on possible utilisation of renewable fuels whereas the other two are concerned with the experimental work on solar water desalination and harnessing electrical energy as a byproduct during solar distillation, i.e. solar still as a thermo-concentration cell.

Plans for future work include field study of the results obtained in the solar still project and utilisation of the results on photogalvanic and thermo EMF in conjunction with distillation in solar stills.

Mahatma Gandhi Memorial College, Udupi.

Work on solar energy utilisation devices was started in 1978. During the period several solar utilisation gadgets including solar water heaters, ovens and solar dryers have been developed.

Current projects include (1) Development of solar water heater of plastic pipes (thermosiphon) sponsored by the Department of Science and Technology. (2) Development in solar concentrator for easier fabrication with G1 Sheets, (3) Development of solar quick-line (burner) producer, (4) Solar instant water heater which can heat 50 or 100 lit. of water in 30 minutes to one hour, for hotels, industries, (e) Solar cooker for cooking inside the house and (6) Solar steam cooker for hotels.

Meerut University, Meerut.

Work on utilisation of solar energy was initiated in 1977. A sprary technique for cadmium sulphide thin films and a prototype solar pump was developed.

Research is being continued in areas of cadmium sulphide thin film solar cells, solar stills, solar pumps and solar heaters. Future research is envisaged to be in the folliwing areas:

1. Development of thin film solar cells without copper sulphide.
2. Development of solar pump which does not require any moving part.
3. Development of a portable solar still.

Publication

An application of gas equation, COSIP News Bulletin, 1980.

Nagarjuna University, Nagarjunnagar.

The Department of Physics initiated work on solar energy during August 1978. To start with an elective subject on solar energy for the final year students of M.Sc. course was taken up. Subsequently, M. Phil programme on solar energy (by Researh) has started.

One of the ongoing research projects includes "Development of Solar Energy System for Tobacco curing process". This project was sponsored by the Department of Scinence & Technology, New Delhi during February 1980.

Pyranometer for solar radiation measurements and sunshine recorder for measuring hours are available in the department. Also test facilities are available for solar air heaters.

List of Publication

1. System design for tabacco curing process by utilisation of solar energy. Paper presented at the Renewable Energy Sources Conference held at Bangkok during January 1981.

2. Tobacco curing by utilisation of solar energy'. Paper to be presented at the International Solar Energy Society Conference, Brigton, U.K. during August 1981.

Regional Engineering College, Kashmir.

Work on solar based winter heating systems started in 1966. Main products developed include solar water heater, solar air heater, wood/charcoal based room heater, energy saving central heating convector, electric heater-cum-humidifier, etc. Current ongoing projects are:-

1. Solar supplemented hot water based central heating.
2. Solar water heating/air heating
3. Passive solar heating/cooking.
4. Development of modern room heating system.

AGRICULTURAL TOOLS RESEARCH CENTRE

Bardoli

Agricultural Tools Research Centre is a voluntary Organisation working for overall development through various appropriate technologies for the last 22 years. It was founded in 1959 to develop improved agricultural hand tools and bullock driven implements for small and marginal farmers of the country. During the last few years, it is increasingly felt that solar energy and bioenergy are two most suitable alternative energy sources for India. Hence through detailed studies the centre started experimenting with prototypes of different designs of biogas plants. About 4 years ago the centre developed a flat plate box type solar cooker.

Completed Projects

About 55 to 60 improved scientific agricultural hand tools and bullock driven implements have been designed and developed. These tools and implements are being manufactured and marketed by the centre's sister concern - Yantra Vidyalaya, Bardoli. The tools and implements are very well appreciated and accepted by the farming community in the country and their demand is increasing.

Domestic fuel is first and foremost priority in rural India. The flat plate, box type solar cooker was well accepted in rural areas. About 800 solar cookers manufactured by Yantra Vidyalaya were already marketed till March 1981. A solar cooker with two cover glasses, one reflector mirror and four folding type legs costs Rs.550/- including 4 aluminium cooking utensils.

A gobar gas plant with iron gas holder and a garbage gas plant were erected at the centre about 10 years ago. In garbage gas plant, methane gas is produced out of organic agricultural waste. It has been working very well. About a year ago a new type of gobar gas plant with fixed R.C.C. roof was

designed and has been erected. In this gas plant iron gas holder is completely eliminated. Total cost of the plant is 30 to 50% less than the conventional plant. Recent studies have also shown the conventional gobar gas plant with iron gas holder can be converted into a fixed R.C.C. roof plant.

On-going Projects

Current research in solar energy sector aims at: (1) Further improvements in the performance of solar cookers and to develop different models of solar cookers of different costs suitable to various class of people. A farmer's model solar cooker costs only 50 to 60% of the cost of present family size model (2) Experimenting with different designs of small capacity solar stills for rural medical use, etc. Few orders for these are also received.

Investigations with biogas plants have the following objectives: (1) At an earlier stage, in the fixed R.C.C. roof gas plants, gas leakage was found in few cases. Later, it was found that the cause for gas leakage was improper workmanship of the artisans at the time of erection. Now a constructional procedure has been developed to rectify this problem. Training of the artisans and masons is essential for constructing fixed R.C.C. roof gas plants without iron gas holder. (2) To develop gobar-cum-garbage gas plant with a continuous gas production, so that farmers who have less quantity of cow-dung can also have a gas plant by adding various agricultural organic wastes to the cow-dung.

Teaching and training programmes undertaken by the centre includes: (1) Theoretical and practical training for post graduate students in science and technology for rural development, particularly for utilization of solar energy and biogas energy. (2) Training programmes for artisans for manufacturing agricultural tools and implements and solar cookers. (3) Publishing literature for mass education.

List of Publications

1. Gobar Gas Plant without Iron Gas Holder.
2. Garbage Gas Plant.
3. Agricultural Hand Tools for Small and Marginal Farmers.

Communicated by: Mr. Mohan Parikh (Director) and Mr. Rahul Parikh (Research Engneer), Agricultural Tools Research Centre, Suruchi Campus, Bardoli 394 601.

C C SHROFF RESEARCH INSTITUTE

BOMBAY

The areas of research being pursued at the CCSRI may be broadly classified as

- Energy, more specifically Renewable Sources of Energy;
- Pollution Control;
- Water Management; and
- Chemicals.

ON-GOING PROJECTS:

A number of interesting projects have been undertaken at a reasonable scale in the areas of "Renewable Resource Management". As a natural and direct means of converting solar energy, research is carried on trees and other vegetation, to locate hardy and fast growing trees of high fuel value.

The following projects give an indication:-

1. Energy Plantation at Jambulpada: A mini plantation of about 2 hectres on hilly waste land at Gathemal, near Khopoli in Kolaba District, Maharashtra has been established since last three years. The programme is financially sponsored by M/s. Excel Industries Ltd., and the expertise and advice is provided by CCSRI. Health and growth of the plants is under periodical observation for the morphological parameters. There are 35 species and the number of trees are about 6000.

2. Energy Plantation at CCSRI: On the site of the Institute at Goregoan - an industrial suburb in Greater Bombay, about 2000 trees are planted. These are of 18 different species. The dormancy period is studied and suitable pretreatment is investigated. Artificial environment is provided to species to study the effect of different soils and manures and temperatures. An effort is made for developing varieties which have maximum photosynthetic area. The effect of foliar sprays in terms of consumption of fertilizer is also studied.

A waste water nalla has its source about 8 K.M. north of the estate and runs through it, within the site of CCSRI. Interesting studies on the contents of the nalla water are made. Part of the nalla water are used for the irrigation of some of the botancial species. On the bank of the nalla, on both sides many of the botancial species like Leucaena and sapota are growing in a very healthy condition.

In front of CCSRI, a proto-type solar still is constructed. Solar energy is used here for the distillation of water. In the fair weather about 60 litres of distilled water are obtained, every day. This quantity is sufficient for daily laboratory experiments.

At the backside of CCSRI, trapezoidal shaped pond covering an area of $225m^2$ is excavated and then "constructed" with the botanical species on all the sides. The soil removed during excavation process is utilised for filling the adjoining land. This new land is then used for the cultivation of banana plantations as well as vegetables. The pond gets water from subsoil region. The water from kitchen washings, laboratory washings and also toilet washings. The aquatic eco-system of the pond, nitrogen fixation of the botanical species, high biomass producing species, waste water cleaning species and nutritional species are studied.

The "Pond Ecoweb" as it is called, also contains some animal, cules, snails, fishes and ducks. These are used for studying biological control of pollution and prey and predator theory. Pigs also form the part of this system. They are fed on the waste from kitchen as well as on the water Hyacinth and typha and other weeds. And their fecal matter in the pond is used as food by the fish larvae. The pig-dung is also tried as biogas feed.

In association with the Research Co-ordinator of Tata Energy Research Institute, the work of making cowdung without cow is accomplished successfully by utilising Dycus Technique. These simple experiments are performed. Large polythene bags are filled with different weeds available from pond as well as from the fields. They are weighed in different propositions and filled in the bags and tied and kept for anaerobic digestion in the hot sun.

RESEARCH FACILITIES:

Further research is proposed in the areas of solar energy and bio-conversion. CCSRI has now adequately equipped laboratories at Goregaon, Bombay to undertake (i) Waste water analysis; (ii) Pesticides effluent analysis; (iii) Soil analysis; (iv) Analysis of several raw materials; (V) Analysis of intermediates. It also has 8 scientists, 2 technologist, 4 technicians and 30 others working as staff of the Institute. CCSRI is ably guided by its Research Directors Shri Ashwin C. Shroff and Dr. R.A. Kulkarni. The Institute also runs a course on 'Diploma in Industrial Research and Management' (DIRM) and is recognised by Bombay University for research work leading to M.S.c. and Ph.D degress in Chemistry.

Prepared from the published reports available at the Documentation Centre, Tata Energy Research Institute, Bombay.

CENTRAL BUILDING RESEARCH INSTITUTE

ROORKEE

Growing apprehension regarding fast depletion of conventional energy resources has led to increased activity on research and development work in renewable energy resources particularly solar energy. Central Building Research Institute, Roorkee has been one of the first institutions in India to have ventured in this direction, though not in a big scale. Investigations on solar water heaters were started some time in 1963. During the past several years persistent efforts have been made to design and develop various types of solar water heaters to cope with the demand of hot water for domestic and community uses. This has resulted into three commercially viable units of different specifications. More recently attention has been paid to the development of an efficient and economic solar space heating system. Solar space heating is likely to become another large scale commercial use of solar energy in buildings particularly in hilly regions and northern plains of the country. Currently work is in progress on an integrated system for summer cooling and winter heating using rock bed storage. Some work is also being done on passive cooling and heating through specially designed roofs. Considerable work has also been done on a solar timber seasoning kiln. A brief description of work done and/or in progress on these topics is given below.

Solar Water Heaters

The following three types of solar water heaters have been designed and developed at this Institute :

1. Domestic solar water heater: This unit has been designed with a view to provide 140 litres of hot water at a temperature of about 50°C on winter mornings at about 7.00 hrs. This amount of water is sufficient to fulfill the requirements of a family of five persons. It essentially consists of a flat plate solar collector, a properly insulated storage tank for overnight storage and circulation pipes. This storage tank is placed slightly above the upper edge of

the absorbers to the storage tank. On cloudy days or when the load exceeds the design value, a thermostatically controlled immersion heater (1.5 KW) can be activated . Some units of this type have been working at Roorkee for many years without any trouble. The present cost of this solar water heater is about Rs.2000/=.

2. Large size solar water heater: This unit has been designed to heat 600 litres of water from 10° to 55° C on clear sunny days during winter months. As natural circulation of water is rather difficult, in this case (forced) circulation is accomplished with a booster pump of 1/8 HP capacity which is thermostatically controlled. This unit is particularly suitable for meeting the intermittent demands of hot water in hostels, hospitals and large kitchens. Recently this type of solar water heater was installed at R.K. Mission Hospital, Kankhal, Hardwar which is giving satisfactory performance. Power consumption by the pump is very nominal, i.e., about 0.25 kW/day.

3. Pipe type solar water heater: This unit is an improved version of low cost solar water geyser. It consists of eight pipes fabricated from G.I. sheets whose total capacity is 100 litres and which performs the dual function of absorbing heat and storing the hot water. Apart from its built-in storage capacity for day time use it could be coupled to a separate small storage tank placed in the bathroom or kitchen or electric geyser for overnight and early morning use. The temperature of water in the heater is maximum at about 15.00 hrs. (67-70° C) and around this time it could be drained to a separate storage tank or electric geyser tank.

This unit is suitable for meeting the daytime requirements of hot water such as in office canteens, toilets and homes as well. It can also be coupled to electric geyser for saving electrical energy through preheating of water besides providing hot water during load shedding period.

Solar Space Heating Sytem

Solar water heating is now an almost well developed technology. Apart from this, space heating of building by solar energy is being accepted as a

means for energy substitution. Work is continuing to design and develop an efficient and economic solar space heating system, suitable for heating small and medium sized rooms. The solar heat is collected by flat plate collectors installed on the roof of the building. Water is used as the heat transport medium. The hot water stored in an insulated tank is circulated through radiating panels placed in the room to be heated. The radiative and convective losses from the radiator heat the room to comfortable level, i.e. 21°C. Its performance has been found to be satisfactory. The observations show that the temperatures obtained in the room are about 5-6°C higher than in the unheated room and its efficiency is about 40%. A demonstration unit has recently been installed for heating a portion of the Institute's Library.

The feasibility of an integrated water and space heating system for meeting the requirement of hot water supply as well as heating of rooms has also been studied. The space heating system described can be modified for this purpose by simply providing a separate fresh water tank of appropriate capacity with a tubular heat exchanger fitted inside.

Research and development efforts have also been directed towards design of another system utilising rock bed storage for both winter heating and summer cooling. Studies are in progress for developing such a system so as to cater for year round thermal comfort in buildings.

Passive system of Heating and Cooling

The feasibility of cooling the building by combined effect of evaporating cooling of air and inducement of air motion (utilising solar energy incident on a specially designed roof) is currently being studied. The solar heat absorbed by the roof heats up the air within the space provided near the ceiling which in turn rises up due to its lower density and is replaced by evaporatively cooled incoming air at the floor level in the room. The room is designed as a solar air heater and is suitably oriented to recieve optimum amount of solar radiation during summer months. To minimise the radiation heat gain from the ceiling adequate insulation is provided below the heated air space. The work is in progress on increasing the efficiency of this system. This system has also been used for heating in winter with the use of movable insulation below the ceiling.

Solar Timber Seasoning Kiln

The work on a solar timber seasoning kiln which could be operated with thermal circulation of air was started some time back. Studies have been carried out on the design and performance of the Kiln. Some of its salient features are given below:

A black painted G.I. sheet of 22 SWG having an area of 1.5 m^2 is used as solar collector. The glass sheet is fitted above it at a distance of 5.0 cm to facilitate air movement. The whole unit is attached to the bottom of south wall of the seasoning chamber and oriented at an appropriate angle. The floor area of seasoning chamber is 12.8 m^2. Its north wall is of brick masonary and has a door. The other three walls are made of glass and are double walled. Black painted aluminium fins (3.6 m x 0.7 cm) of 24 SWG were fitted in the south wall over an area of about 11 m^2. The roof was black painted corrugated G.I. sheet inclined at a slope of 27°. To provide stack effect inside the seasoning chamber a chimney (30 cm x 30 cm x 180 cm) was fixed vertically in the roof.

Performance of the kiln was studied by seasoning Mango (Manfigera indica), Jamun (Eugeria Jambolana) and sal (sohrea robusta) woods. The plants of mango and jamun woods were taken in the size 300 x 25 x 50 cm.

The sal wood was studied in the form scantlings in the sizes 300 x 10 x 10 cm and 30 x 7.5 x 5.0 cm. Initial moisture content of the three woods were 41, 37 and 32% respectively. Time taken in drying upto 10% moisture content by the various woods is tabulated below:

Wood	Time taken for seasoning	
	kiln (10% m.c.)	Air (10% m.c.)
Mango	35 days	1 month 27 days
Jamun	2 months 20 days	3 months 17 days
Sal 7.5 x 5.0 cm	67 days	Reached upto 27% m.c. within 67 days.
Sal 10 x 10 cm	85 days	After 4 months dried upto 17% m.c.

The kiln has a capacity to season about 3 cubic metres of wood and cost of construction was Rs.8500/-. However, a similar kiln having capacity to season 15 cubic metres of wood has also been designed and its cost of construction is estimated at Rs.15,000/-. The advantages of this kiln are :

1. Kiln requires no other source of energy for its operation except solar energy.

2. It is based on the principle of thermal circulation of air. Hence there is no operational cost.

3. It is easy to construct even at village level.

4. All types of woods can be seasoned in it.

Expertise Available At The Institute

The Institute has almost perfected the design of various solar water heating systems and is in a position to provide expert advice in this field to industry and educational institutions. The solar water heating systems developed at this Institute are licensed to four firms in the country through National Research and Development Council and several units have been manufactured and sold to clients. The solar space heating system is also likely to be finalised in early 1980 whereafter it would be possible to provide necessary guidelines for its design and installation. Some clients have shown their interest in the solar timber seasoning kiln too.

Acknowledgement

This write up is a review of research and development activities on solar energy at CBRI, Roorkee and is published with the permission of the Director. Thanks are also due to Dr. B.K. Saxena for useful discussions.

References

1. M. Chandra, R. Ganguly and J.S. Puri.
"Solar water heaters for low temperature applications".
(To be published in Energy Management.)

2. H.P. Garg and R. Ganguly.
"Solar water heater" IE (1).
Journal IDGE, Vol.50, 1970.

3. S.K. Kaila, R. Ganguly, J.S. Puri and N.K.D. Choudhury.
"Pipe type solar water hater".
National Solar Building Technology Conference, London, 25-29 July, 1977.

4. H.P. Garg, R. Ganguly and J.S. Puri.
"Forced convection solar hot water system".
Research and Industry, 16 (1), 1971, 31-34.

5. M. Chandra, R. Ganguly and Puri, J.S.
"Application of a low cost pipe type solar water heater".
(To be published)

6. C.L. Gupta, H.P. Garg and R. Ganguly.
"Solar-cum-electric water heater".
The Indian & Eastern Engineer, Jan. 1969, 21-24.

7. H.P. Garg, R. Ganguly and J.S. Puri
"Solar room heater".
Reasearch and Industry, 17 (4), 1977, 129-133.

8. S.K. Kaila, R. Ganguly and J.S. Puri.
"Performance of a solar space heating system".
Brazilian Energy Congress, Rio de Janeiro, Dec. 1978.

9. M. Chandra, R. Ganguly and J.S. Puri.
"Experimental evaluation of a solar space heating systems".
Proc. Natl. Solar Energy Convention IIT, Powai, Bombay, Dec. 1979, 187-192p.

10. M. Chandra, R. Ganguly and J.S. Puri.
"Solar space heating system".
Technical Note, Central Building Research Institute, Roorkee, 1980.

11. N.K. Garg, M. Chandra, Shyam Lal, R. Ganguly and J.S. Puri.
"Passive cooling of buildings - inducement of air motion".
Presented at the Symposium on Renewable Sources of Energy organised by National Academy of Sciences on the occasion of its Golden Jubilee, 24-26 Oct., 1980, Allahabad.

12. Y. Singh and Ashok Chandra.
"Design of solar timber seasoning kiln".
International Solar Energy Congress, New Delhi, Dec. 1978.

13. Y. Singh.
IPIRI Journal 1976, 42-44.

14. Singh, Y and Goswami, N.L.
Proceedings of Solar Energy Convention of India, Bhavnagar, 1978, 291-298.

15. Y. Singh.
Proceedings of Seminar on Potential Woodbased Industries in the Development of National Economy, FRI & C, Dehradun, 1976, 58-62.

16. Y. Singh.
"National draft based solar timber seasoning kiln".
Paper presented in the Workshop of Solar Timber Seasoning Plant, Allahabad, 16 Feb., 1979.

Communicated by : M. Chandra, R. Ganguly and Y. Singh, Central Building Research Institute, Roorkee 247 672.

CENTRAL ELECTROCHEMICAL RESEARCH INSTITUTE

Karaikudi

The Institute was founded in 1953 to help the development of eletrochemical industry in India. Areas of research include batteries, corrosion, electrodeposition and metal finishing, electro-organic and inorganic products, electrothermics and electrometallurgy, fundamental electrochemistry and solid state electrochemistry and instrumentation. Research on renewable sources is mostly in the areas of thermoelectric generators, selective coatings, solar cells and photoelectrolysis and photoelectrochemical energy conversion. The work which began in 1975-77 is in progress.

Thermoelectric Generators

The work on thermoelectric generators started in 1975. Thermoelectric generators of bismuth based alloys have been prepared and are found to work satisfactorily. Bismuth, antimony, selenium and tellurium with proper dopants are the materials used for these bismuth based alloys. Experimental set up for preparing homogenous alloys and measuring thermoeletric characteristics have been designed and fabricated. A small module containing 6 couples gave an output of 110 mv at 500 uA for a temperature difference of 150° when connected across an optimum load. Obviously, appropiate connection in the series and parallel of sets of number of small modules can result in a sufficient higher output.

It is proposed to make bigger modules by connecting a number of smaller ones in series and parallel and by concentrating solar energy to get the maximum output under optimised conditions.

Selective Surfaces

The institute, for the last three years, has been engaged in research on selective surfaces. A selective absorption surface was obtained by a thin

coating of semiconducting mixed oxides of copper and chromium. The thin coating is achieved by using a suitable binder on aluminium substrate. This surface is found to have a very high absorption in solar spectrum namely, upto 1.5 um and good reflectance in the thermal infrared region, i.e., beyond 1.5 um.

Work on preparing bulk quantities of the selective coating material and to coat them on larger areas for field trials will be undertaken in the future.

Solar Cells

A project on cadmium sulphide solar cells was started in 1977. Cadmium sulphide layers have been formed on molybdenum substrates by sintering technique. On the top, p-type layers have been deposited by chemical decomposition technique. After processing, cells have been formed giving an output of 175 mV and 320 uA at 80,000 lux sunlight. The photosensitivity lasts upto one week.

In another method, pellet type of photovoltaic cells have been made giving output of 150 mV and 7 uA at 80,000 lux. Even though the values appear to be small, the output is still maintained (that is upto 20 months).

Yet another type of cell with CdS sintered on ceramic substrate and with one ohmic and one non-ohmic contact on top has been made. The layer type photovoltaic cell gives on output of 100 mV and 30 uA. This also functions well for more than six months.

The process for making cadmium sulphide photoconductive cells was subcontracted to M/s. Electron India, Madras 41, who are marketing the cells as well as gadgets using these cells. Cadmium selenide cells have been referred to the National Research Development Corporation of India (NRDC).

Cadmium sulphide solar cells by the sintering method are being made with a view to enhance the output. Shelf life studies are being made to assess the performance of the studies. it has been observed that layer type cadmium

sulphide photovoltaic cells without heat treatment is above to give 200 mV 65 uA at 80,000 lux after six months. Also, cadmium sulphide-thallous sulphide heterojunction cells have been made giving output of 200 mV and 50 uA at 80,000 lux.

In the near future, work on cheap and large area cadmium sulphide heterojunction photovoltaic cells will be intensified with the main aim of getting higher output based on three approaches, namely CdS-Cu_2S and CdS-Tl_2S by sintering method on to a conducting substrate and CdS-Cu_2S or Tl_2S by pellet method.

Photoelectrolysis & Photoelectrochemical Energy Conversion

Research on semiconductor-liquid junction photocells was started in 1977. In the initial experiments, ZnO and highly photosensitive poly-crystalline CdS and CdSe coated ceramic substrates were employed. Zno coated stainless steel base and also pellets were employed. A two compartment cell (separated by a sintered glass partition and provided with an optical glass window) was employed. A platinised gauze was used as the counter electrode.

A number of electrolyte systems were employed. The photocurrents and photovoltages were measured employing a 200 W projector lamp as the light source. An alkaline perchlorate solution was found to give good photoeffects. The photovoltages were of the order of 0.08 to 0.47 V under different concentrations and intensities of light. The photocurrents varied from 42 uA to nearby 200 uA under the above conditions. The studies on the effect of addition agents to enhance the photoeffect and increase the stability of the systems were begun.

An interesting photogaradic effect has been observed in CdS and CdSe when the effect of an applied a.c. different frequency was studied.

Laboratory and Test Facilities

Furnace, upto 1000°C, 5½ digits DPM; Philip's GM 6020 DC microvoltmeter; Motwane microhmmeter; Hindi hivac mobile vacuum pumping

system and a fabricated set up for measuring thermoelectric chracteristics.

Alphameter for measuring absorptance, emissometer Model DU for spectral energy distribution studies.

Lux meter (0-5000 lux); Carl-Zeiss monochromator (Prism type, Model SPM 2): Hind Hivac vacuum coating unit model 12A4; Philips electron microscope model EM75 and Reichert Universal microscope of Austrian make.

Project Team

Dr. C.V. Suryanarayaa, Mr. V. Sundaram, Mr. N. Nagarajan, Mr. K. Nagaraja Rao and Mrs. Mary Julina Chockalingam.

List of Publications

1. A thermoelectric generator useful for solar energy conversion.
   Proceedings of the 3rd Conference on Power Sources, March 1979.

2. Cadmium oxide as contact material to cadmium sulphide and cadmium selenide photocells.

   International Seminar on Applied and Oriented Basic Electrochemistry by SAEST, Dec 1980.

3. Cadmium sulphide heterojunction photovoltaic cell for solar energy conversion.

   Accepted for publication in Transactions of the SAEST.

4. Sintered cadmium sulphide layer electrode in photoelectrochemical energy conversion.
   Presented at the 3rd National Conference on Power Sources held at I.I.Sc., Bangalore, March 1979.

5. A.C. effect on the photopotential at the CdS-electrolyte interface. Paper presented at the Seminar on Recent Trends in Electrochemistry held at the Indo-Soviet Cultural Centre, Madras, Dec. 1979.

6. Sintered cadmium selenide layer electrode in photoelectrochemical energy conversion.

   Paper presented at the International Seminar on Applied and Oriented Basic Electrochemistry held at the I.I.T., Madras, 9-13, Dec. 1980.

Communicated by: Dr. C.V. Suryanarayana, Head, Div. of Chemical Physics, Central Electrochemical Research Institute, Karaikudi 623 006.

CENTRAL ELECTORNICS ENGINEERING RESEARCH INSTITUTE

Pilani

Central Electronics Engineering Research Institute (CEERI) has undertaken a programme on the development of single crystalline silicon concentrator solar cells. The research and development work on solar cells at CEERI is funded by the Department of Science and Technology, Govt. of India and partially by the Council of Scientific and Industrial Research (CSIR).

Initially CEERI developed 1 watt panels using small area silicon solar cells. Recently, CEERI has fabricated successfully a 40 watt concentrator silicon solar cell panel first of its kind in India, using large area cells. Items such as small water pump, fan, tubelight, TV, etc., were operated by charging a 12 V car battery by the panel.

The 40 watt panel developed at CEERI consists of 40 single crystalline silicon solar cells of n^+p junction type fabricated in the solid state device laboratory. The concentrated sunlight is provided by using equal number of square plastic Fresnel Lenses of size 6" x 6". The silicon solar cell area is 5 cm^2 and the top grid has been designed specially for concentrator applications, where series resistance is of great importance. The sunlight concentration is of the order of 30 Suns. The best fabricated solar cells exhibited 14% efficiency at one sun condition and 12% efficiency at 30 Suns. Panel tracking is done manually. In an effort to develop new processes for the fabrication of solar cells, back surface field (BSF) silicon solar cells of n^+pp^+ type (area 4 cm^2) were fabricated. The best measured efficiency of a BSF solar cell was about 15.34% total area at one sun conditions (17.43% if active area is considered).

Presently, work at CEERI is progressing to improve the cell processing to obtain high efficiency solar cells for fabricating higher capacity panels (100 W and 1 kW). Work is also in progress to reduce the cost of the solar cell by improving and adopting new processing techniques.

CEERI has laboratory facilities for the cell fabrication and testing, which are constantly being updated and improved.

List of Publications

1. "Low cost solar cell manufacturing technology" by R. Van Overstraeten and R.K. Jain. Proceedings International Symposium on Solar Science & Technology, Nov. 25-Dec. 4, 1980, Bangkok, Thailand (To be published).

2. "Iron implanted silicon solar cells and their economics" by R.K. Jain. Proceedings Workshop on Physics of Ion Implanted Solids and Thin Film Surfaces, 17-19 Dec., 1980, Kurukshetra University, Kurukshetra, India (To be published).

3. "Solar cell manufacturing technology" by R. Van Overstraeten and R.K. Jain. National Solar Energy Conversion, 19-21 Dec., 1980, Annamalainagar, India.

4. "Recent advances in ion implanted silicon solar cells" by R.K. Jain. Proceedings International Workshop on Ion Implementation, Laser Treatment and Ion Beam Analysis of Materials, Feb. 1981, BARC, Bombay, India (To be published).

Communicated by : Dr. R.K. Jain, Scientist, S.S.D. Div., Central Electronics Engineering Research Institute, Pilani.

CENTRAL INSTITUTE OF AGRICULTURAL ENGINEERING
Bhopal

The Institute was established by the Indian Council of Agricultural Research (ICAR) in February 1976. One of the activity at the Institute relates to the development and efficient utilisation of energy resources for agriculture. The following are the ongoing projects in energy research:

1. Solar Energy

1.1 Sun-drying of Chill crop

Chilli crop is grown on 75,000 ha in India. Chillies are harvested at 80% moisture content and are required to be brought down to 10% for safe storage. They are usually sun dried by the farmers on mud plastered floor. At CIAE, drying of chillies on 7 different surfaces, namely, tarpaulin (Olive green), Jute mat, black polyethelene white polyethelene, concrete floor and white canvas were tried. Mud floor was used as control. The drying was most rapid in the solar cabinet dryer and was evaluated by tarpaulin, cement concrete floor, black polyethelen and mud floor respectively.

The design of the above solar cabinet dryer was improved by incorporation of an aspiration device. A chimney of 2 metre height painted black was installed on the cabinet dryer to get a draught of air. The addition of the chimney increased the air flow from 0.8 to 1.1 m/min during the experimental work.

A solar stalk aspirator is being tried out in combination with the cabinet dryer to make it independent of the direction of the wind for creating the draught.

1.2 Solar batch drying of groundnut crop

A solar batch dryer has been developed for rapid drying of groundnut crop. The dryer consists of an aeration bin, solar collector and electric blower.

Aeration bin is a cylindrical structure with perforated false floor 250 mm above the bottom creating a drying chamber 950 mm deep and 250 mm deep plenum chamber. A semi cylindrical absorbing type solar collector is developed on the south facing wall of the bin. A centrifugal blower is used for circulation of heated air. The dryer is being tested for groundnut drying with a batch capacity of about 1 tonne.

1.3 Solar hay drying

A room batch dryer of 0.5 tonne capacity (green fodder) has been designed for solar drying of hay on the basis of results obtained during preliminary experiments carried out at Bhopal. The size of the room is 4.5 m x 4 m x 3.9 m.

1.4 Solar water heating

A 200 litres/day capacity solar water heater has been fabricated and tested. The insulating material used are agricultural waste such as rice husk and saw-dust. During the test it was found that it provides hot water 55-59°C in winter evening and 45-50°C in winter morning.

The Institute purchased commercial water heaters marketed in India and are being evaluated for their performance.

1.5 Solar cooking

The Institute has flat plate solar oven designed and developed at ATRC, Bardoli and its performance is being evaluated. It was observed that when the containers were not loaded with any material their temperatures rises to 90°C - 99°C. However, when the containers are loaded with 250 gm rice in each contaier, it ranged betwen 75-85°C using four containers. The cooking time varied between 2.5 to 3 hours for cooking 250 gm rice in each container. The experiment was carried out in winter months.

2. Wind Energy

The Institute's farm has a windmill, WP-2 model of NAL design (National Aeronautical Laboratory, Bangalore) which was installed in the 1960's when the farm belonged to the State Governmnt, Madhya Pradesh.

The windmill rotor diameter is 4.87 m and its tower height is 9.76 m. It has 12 galvanised iron blades, bolted to the wheel to facilitate interchangeability. The studies are being conducted to evaluate its performance for irrigation. A Savonius type windmill of IRRI design (International Rice Research Institute, Manila, Philippines) is being fabricated at the Institute. The availability of wind power and wind-velocity profile at the site are also being recorded. A consolidated and comprehensive monograph on the "Survey of existing windmill and review of literature on windmills" is also under preparation.

3. Energy from Animal Wastes

3.1 Studies on gobar gas plants

There are about 80,000 biogas plants in the country. These are of various designs and capacities. These designs are rather crude to the engineering principles. Besides, during winter months the rate of gas production is reduced due to the lower ambient temperatures. Studies on gobar gas plants have been undertaken to evolve an efficient economical design which can operate satisfactorily even in winter months. A model plant has been designed and fabricated at the Institute alongwith a solar water heater, based on the principle of thin layer heating, to maintain the optimum temperature in the plant. The plant is provided with a stirrer for desired agitation of the slurry and its pH is maintained by regulating the feed rate. The studies are under progress.

3.2 Design & Development of gobar cells

A unit gobar cell is a bio-electrochemical cell which gives a direct current electricity. This unit cell consists of a pair of electrodes (positive and

negative) and small quantity of cowdung in cylindrical plastic container. The Institute has succeeded in developing one such cell which gives a potential difference of 0.8 volts and 12-15 mA of short circuit current (with carbon and zinc as electrodes). The cylindrical plastic container of 40 x 50 mm is found to be most practical and economic container and holds 60 gm of fresh dung. Series-parallel configuration of the cell has been designed to operate the transistor receiver sets. The studies are under progress for optimisation of electrolyte concentration, size and shape of electrodes etc.

4. Energy from Agricultural Wastes

India annually produces an estimated crop waste weighing 200 million tonnes out of which about 50 million tonnes is used as domestic fuel. The average heat content (calorific value) is about 4000 kcal/kg of crop waste and it is estimated that these wastes can generate 0.23 MWh of energy. There is need to carry out research on briquetting or pelletizing these wastes and on suitable combustion units for industrial applications and stoves for domestic purposes. The following projects have been initiated at CIAE for this purpose:

4.1 Development of a briquetting machine for paddy husk & sawdust for curing of tabacoo

Coal is the conventional fuel for curing of virginia tobacco. However, with prevailing global energy crisis, it is felt that coal should be replaced by locally available cheap alternative sources. Paddy husk and sawdust are available in adequate quantity. However, because of their certain physical characteristics, like, fine size, shape and low bulk density, these products do not find direct popular application. This problem can be minimised by their briquetting locally. The objectives of the above project are: (i) to test and modify the conventional coal briquetting machine for briquetting paddy husk and sawdust; (ii) to study the fuel properties of briquettes this made; (iii) to study the performance of these briquettes in tobacco curing; and (iv) to study the economics of briquetting. The project is initiated at the request of Central Tabacoo Research Institute, Rajahmundri (A.P.).

4.2 Generation of producer gas

This project is initiated with the following objectives: (i) to design and fabricate a pilot plant for producing producer gas from agricultural wastes such as rice husk, ground nut shells, cotton sticks, etc.; (ii) to determine the rate of gasification optimum conditions for gasification and heat value of producer gas and its analysis; and (iii) installation of producer gas plant for crop drying.

4.3 Alcohol production from agricultural wastes & molasses

An attempt is being made at CIAE also with the following objectives: (i) to study the existing production and synthesising process of ethanol/methanol and (ii) to carry out technical and economic feasibility studies for design and installaton to two pilot plants for producing ethanol and methanol.

4.4 Testing engines using ethanol as fuel

The project is initiated with a view to, (i) characterise various fuel mixture in varying proportions; (ii) to install and operate the petrol and diesel engines by varying fuel proportions; and (iii) to carry out the performance test on the engines

5. Studies of Social Forestry

In view of the shortage of firewood and fodder in rural areas, a research project is being initiated to carry out studies on growing short rotation trees which are suitable both for fodder and fuel. A few varieties such as Kubabul, Seru, etc. have been identified and will be grown on a 0.25 ha plot. The calorific value of various tree species grown in the district of Bhopal will be evaluated.

A few improved domestic cooking stoves of various designs have been fabricated at the Institute and are being evaluated. The successful models will be demonstrated to farmers and their families for popularisation and adaption under the lab-to-Land programme.

Energy Survey of a Village

An energy census is being carried out for a village called "Islamnagar" in the district of Bhopal to estimate the energy required for crop production, raising of cattles, and tansportation by various categories of farmers and landless labour. The energy required for domestic cooking and transportation of domestic water is also being investigated. The survey work has been completed and the analysis of data is in progress.

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CENTRAL MECHANICAL ENGINEERING RESEARCH INSTITUTE

Durgapur

One of the on-going research projects at CMERI is to find out different parameters for optimisng the generation rate of biogas from water hyacinth - an aquatic herb of the pickerel weed family (Ponterderiaceae), that makes vast water areas unsuitable for fish culture.

After several laboratory experiments and laboratory scale-up studies the CMERI scientists have worked out the generation rate pattern of biogas by anaerobic digestion of water-hyacinth. The fuel gas obtained by this process has a calorific value of about 5,340 KCals/m and contains over 55% methane and about 6% hydrogen. The peak-route generation period remains for about 20 days at 31-35° from 'single charge'. The rate can be maintained by addition of a limited quantity of feed at regular intervals once the peak generation period has started. The decomposed sludge obtained has a high fertiliser value with a good soil conditioning property.

The scale-up laboratory model of the plant, made up of two used diesel drum, is of 200 litre capacity. While one drum serves as a fermentation-cum-gas collection chamber, the other, kept at a higher level, acts as a slurry displacement-cum-pressurisation chamber. A 100 cp (candle power) gas-mantle burner can glow for about 30 minutes after every 24 hours for about 20 days (peak generation period) from single charge of about 10 kg (dry weight) coarsely chopped semi-dried water-hyacinth. This model can thus, also be used for short-time ligting.

After realising certain difficulties in case of fixed concrete dome a laboratory scale up has been designed having floating dome and is under fabrication for study.

A 3,000 litre capacity biogas plant utilising water-hyacinth is in operation at the Central School, Durgapur, to supply fuel gas to its chemistry laboratory. Another plant of the same capacity is under construction to 'feed' the CMERI staff canteen. Both the plants have fixed concrete tops.

The Regional Research Laboratory, Jorhat has been conducting a Commonwealth Science Council project on "Management of water-hyacinth." In August 1979 the CMERI joined hands with RRL (J) to share experiences gained through past efforts. Under this mutual agreement, the CMERI will supply to RRL (J) detailed designs and drawings of the prototype gas-generator models for fabrication at Jorhat and testing under different environmental conditions. The results will help optimise design and operation conditions. The final designs will be passed to the Commonwealth Science Council foruse in Commonwealth countries.

Mixed feed using locally available seasonal leaves of Sal (Seria Robusta) and Mohna (Madhuca India) trees with water hyacinth is under study.

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CENTRAL POWER RESEARCH INSTITUTE

Bangalore

The Institute started research in wind energy utilisation during 1974, and later in 1978. Work on other areas such as steam operated liquid piston pumps and development of fluidyne pump was initiated. A brief summary of the progress is given below :

Steam Operated Liquid Piston Pump

This pump has been developed for burning biomass as fuel such as scrap wood, agricultural wastes and similar materials. It works on the steam expansion and condensation principle for the pumping of water from a depth. An effective condensation mechanism makes cyclic operation of pumping and suction possible. Prototypes have been constructed which pumps about 1200 litres per hour of water over a head of about 22'. Efforts are progressing to increase output and efficiency by using empty oil drums for the cylinder.

Wood Burning Stove

While attempting to improve the combustion zone of SOLP pump, a useful type of stove for burning wood was realised. This would find application for rural cooking purposes. The stove designed could achieve concentrated and less sooty flames which contribute to increase in efficiency compared to the normal village mud stoves. Efficiencies of nearly double the value have been noted.

Development of Fluidyne Pump

The Fluidyne Pump, devised by a UK inventor, works on the principle of oscillation of a water column in a closed tube with the oscillatory power being transmitted to a pumping circuit through a tapping connection. While further developments have not been heard of, a different approach was made by CPRI to the theory of operation and by this means a working laboratory model was developed. A larger outdoor model has been fabricated and is undergoing tests. One area of application of this device would be to pump water from shallow

depths such as from canals to agricultural fields. Since the heat input requirement is nominal, operation from solar energy could be considered to power the system.

Wind Energy Utilisation

A water windmill of the WP2 type designed and developed by NAL, Bangalore was installed and its performance was monitored for about two years. Modifications to its pumping system were carried out to make the unit more reliable. The conclusion on this design was that its cost was too high for the small amount of power output delivered by it.

A 6 KW wind electric generator know as 'Algaier' was installed and its performance was monitored for about a year. This wind electric generator was used to light some flood lights fixed on the top of the CPRI building. This is a wind machine suitable for high wind velocity regions and as such the maximum output ever derived from it in CPRI was only 3 KW. After a couple of years of operation the main bearing of the wind machine broke down and the unit was dismantled.

Another water pumping windmill based on a Dutch design was fabricated and installed in the campus. This unit is still in operation and proves to be promising for large scale application.

Plans for Future Work

New areas of investigation and concepts in all the feasible energy fields are proposed to be attempted. Wind energy investigations will be in the following areas :

1. Development of technically viable and economically feasible water pumping windmills.
2. Development of wind electric generators for small quantities of power.

List of Publications

1. Steam operated liquid piston pump (SOLP) by V.R. Narasimhan and S. Jayaraman. National Solar Energy Convention, 1979, 221-26.

2. "Wind power projects in India" presented at the Symposium on Renewable sources of energy organised by the National Academy of Sciences, Allahabad in October 1980.

3. "Case study of windmill projects in CPRI" presented at a Seminar on "Non-conventional energy sources held at the Institution of Engineers, India, Bangalore in September 1980.

Communicated by : Mr. S. Jayaraman, Sr. Deputy Director, Central Power Research Institute, Post Box No. 1242, Bangalore 560 012.

CENTRAL SALT AND MARINE CHEMICALS RESEARCH INSTITUTE

Bhavnagar

Research activities to utilise solar energy started early in 1964 by recovering water instead of salt from saline water. In 1966, a Principal Radiation Station was established. The decade 1970-80 saw CSMCRI intensifying and diversifying activities in the field and now has programme studies on collectors and concentrators and their use in rural areas, industry and power generation. The Institute has also undertaken work on sponsored schemes and collaborative programmes with other countries, in the field of solar pumps, selective surfaces and development of solar thermoelectric generator and stirling engines.

A project on solar distillation (solar stills) has resulted in installation of plants in villages and lighthouses, to supply drinking water and for supply of distilled water in testing laboratories, workshops etc. The solar still designs with semi-permanent and permanent constructions are modified with a view to overcome problems in operation, maintenance and construction. Plants of 5000 lit/day and 8000 lit/day capacity are supplying drinking water to villages Awania (Gujarat State) and Bhaleri (Rajasthan State). Proposals to install solar distillation plants in salt works and Bitra island under Union Territory of Lakshadweep are under consideration.

Solar Collectors and Concentrators

The work on flat plate collectors is aimed at the development of selective surfaces, mainly black nickel using aluminium and galvanised sheets as base metal. The conditions are being optimised on laboratory scale with evaluation of radiative properties.

In a project sponsored by Tata Energy Research Institute studies on flat plate collecotrs with honeycombs are in progress. Main stress is to optimise the dimensions of honeycombs made from transparent materials.

Shallow pond solar collectors look promising for water heating. These consist of long basins filled with water having two plastic glazings; one floating on water surface and other inflated or supported (with air space) above the first. Experiments conducted have shown that hot water at 60°C and above can be obtained and they are cheaper than conventional collectors. But the problem of maintenance needs to be carefully studied.

Work on design, fabrication, testing and tracking of concentrators of paraboloidal, cylindroparabolic and Winston type is in progress. These are to be used for operation of small ice machines, stirling engines, thermo-electric generators, photovoltaic cells, etc.

Solar refrigeration

The Institute is now concentrating more on development of solar absorption refrigeration systems for cold storages. It has installed an experimental one ton unit which is used for data collection and understanding operational problems, design changes and material failures. It is proposed to install a 10 ton capacity cold storage facility.

A solar ice machine using concentrator and flat plate collectors for regeneration of the solution has been developed. Further work is being done to make it compact and lighter in weight.

Solar water pump

A pump of 10,000 lit/day capacity without moving parts has been installed . It is operated with a field of plate collectors having an area of 9 sq.m and petroleum-ether (60-40) or Hexane as working fluid. Based on the data collected, a final report will be prepared shortly.

Photovoltaic cells

The Institute undertook the work on studying I-V characteristics of available solar cells and effect of concentrators on output. As the cells used

were not suitable for higher concentration ratios experiments were conducted at concentration ratio of 2.5 and with cooling of cells. Output increased by nearly 1.5 times.

Suitability of solar cells for lighting and water pumping has been carried out in collaboration with Central Electronics Ltd., Shahibabad. A 112 peak watt capacity water pumping unit was set up with assistance from CEL in October 1979 and since then data has been regularly collected. Solar cells have shown conversion efficiency around 7.8% whereas the D.C. Centrifugal pump has efficiency around 15 to 20%.

Stirling engine

Work started on the development of a stirling engine (hot air) for water pumping. A set-up with 200 watt output comprising of hot air engine and paraboloidal concentrator was designed, fabricated and tested. The engine is coupled with a simple reciprocating pump. Due to various factors and difficulties in sealing and incorporation of heat regenerators the actual outputs are very low. Automatic tracking of the concentrators is being studied alongwith modifications in engine design.

Solar ponds

Solar ponds accomplish dual functions of collection of solar energy as well as storing it in thermal form at temperatures around 80 to 90 $^{\circ}$C and compared to other systems they are cheap. In 1970 a solar pond of 55 m x 22 m and one meter deep was constructed and it was in opertion for 3 years. A maximum temperature around 80 $^{\circ}$C was noted at the bottom layer.

This work is revived again with an objective of using collected and stored heat for power generation using a suitable turbine unit. A square shapped pond of 40 m x 40 m at the top and 35 m x 35 m at the bottom with 1.6 m depth has been constructed and is charged with saline solution. A heat extraction system in the form of tubular heat exchange is already installed.

Thermal storage

Storage in the form of sensible heat temperatures below 90°C is planned in the work on solar pond. For higher temperatures, mixture of nitrate and nitrites are under investigation. The chemical and thermal stability alongwith corrosion problems are also under investigation prior to heat transfer studies for container design.

Industrial applications

Survey for thermal energy requirements at various temperature levels has been carried out. It appears that prospects of using solar energy to meet heating requirements (hot water, hot air and low pressure steam) in textile industries are good. A demonstration unit of 1500 lit/day of hot water at 70°C has been installed in Jupiter Textile Mills, Ahmedabad and shortly another installation of 6,000 lit/day of hot water at 80°C will be put up in New Jehangir Vakil Mills, Ahmedabad.

Bio-conversion

This work involves studies on cultivation of fast growing plant species yielding fuel and fodder. The latex bearing plants reported to yield hydrocarbon oils are under investigation. The available plant species were analysed and out of them systematic cultivation work is taken up on five plants belonging to Euphorbia and Calotropis species. At the same time laboratory scale work is in progress to develop a process for extraction of the fuel oil from the plant materials.

Rural Applications

Surveys are being carried out to study possible applications of solar energy in rural sector. In a sponsored project by TERI, a survey was undertaken on cooking stoves (choolahs) in Bhavnagar district.

Work is also underway to study the effect of pretreatment of seeds with pulsed concentrated solar radiation. It is reported that this treatment increases the yield.

Laboratory and Test facilities

CSMCRI has fabricational and instrumentation facilities. Due to multi-disciplinary research activities, expertise is available in almost all the fields. Institute has principal radiation station for collection of solar radiation data and instruments for evaluation of performance of solar energy based equipments.

Future programmes

In the coming years it is proposed to lay more stress on the development of collectors (cheap and efficient), solar pond for power generation, industrial application, bio-conversion-particularly on hydrocarbon yielding plants and desalting with solar energy by techniques other than solar stills.

Communicated by : Dr. S.D. Gomkale, Asst. Director, Central Salt & Marine Chemicals Research Insitute, Gijubhai Badheka Marg, Bhavnagar 364 002.

CENTRAL WATER AND POWER RESEARCH STATION
Pune

"Ocean energy" is available in the form of thermal gradients, salinity gradients, waves, tides and marine biomass. The potential sites for tidal power generation in India are in the Gulfs of Kutch and Cambay on the west coast.

Tidal Power

A proposal for the development of tidal power with preliminary studies was initiated in 1975. When two UN consultants visited the Research Station, the details relating to tidal power development were broadly discussed.

The Research Station has been acting in the capacity of an executing agency for laboratory investigations and some of the field investigations for the Tidal Power Project in the Gulf of Kutch. A sum of Rs.218.38 lakhs has been allocated by the Central Electricity Authorities (Ministry of Energy) to carry out the necessary investigations pertaining to the feasibility of setting up a Tidal Power Plant in the Gulf of Kutch.

Laboratory and Test Facilities

The Research Station established in 1916 has been mainly engaged in the field of hydraulic research. Facilities for undertaking studies by constructing physical models as well as mathematical models are available in the Research Station, which is spread over 180 hectares of land with large space available for constructing physical models. Computer facilities are also available for mathematical modelling.

Mathematical modelling requiring larger memory could also be undertaken since computers such as DEC-10 at TIFR, Bombay and ICL-1900 S at the Regional Computer Centre, Pune, are accessible. The Research Station has also established a sophisticated instrumentation and data acquisition system for both field and laboratory investigations.

Plan for Future Work

It is proposed to undertake field investigations in the Gulf of Kutch at selected locations to collect data such as waves, tides, currents, sediment concentration, salinity, fresh water discharge and bathymetry. Organisations such as the Gujarat Electricity Board, Survey of India and others would be consulted for field data collection.

Publications

1. P.P. Vaidyaraman, 'Hernessing of tides for power generation', Seminar on Energy Management, South Indian Steam and Fuel Users Association, Madras, 12-14 March, 1976.

2. P.P. Vaidyaraman, and S.B. Brahme, 'Tidal power generation in India', Proceedings, Institution of Engineers (India), Dec. 1974.

3. P.P. Vaidyaraman, G. Puttaramaiah, and N. Somyaji, 'Possibilities of developing tidal power in India', Proceedings, National Symposium on Hydroligic Problems related to the Development of Power and Industries, IIT, Kanpur, 27-29, Sept. 1976.

4. G. Puttaramaiah, 'Tidal computations for the assessment of Barrier Effects', Proceedings, Annual Convention of Computer Society of India, Pune, 9-12, Jan. 1977.

5. G. Puttaramaiah, 'Hydraulic research for tidal power projects', National Workshop on 'Energy from Seas', NIO, Goa, 15-16, Dec. 1980.

Communicated by : Mr. P.P. Vaidyaraman, Joint Director, Central Water and Power Research Station, P.O. Khadakwasla Research Station, Pune 24.

JYOTI SOLAR ENERGY INSTITUTE

Birla Vishvakarma Mahavidyalaya

Vallabh Vidyanagar

The Jyoti Solar Energy Institute inaugurated during 1979 is attached to Birla Vishvakarma Mahavidyalaya (Engineering College).

Solar Thermal Utilisation

The Institute has erected its own meteorological station wherein solar insolation, maximum and minimum temperatures, relative humidity, average windspeed, etc. are recorded. It has constructed two concentratic collector, three hot water systems and two water stills. Two solar cookers have been fabricated, one oven type and other of paraboloid type. The Institute has erected a large hot air system, consisting of 40 sq.m. roof area. This facility is now being used for preparation of casein and drying of agricultural produce. In addition, the Institute has erected 4 m^2 solar green house, 0.75 m^2 cabinet drier and 0.75 m^2 vertical drier. In the first two, sun's rays fall on the material to be dried whereas in the last one, the sun's rays are indirectly used for drying.

Bio-Conversion

The research in this area is in progress since 1977. The Institute has successfully constructed a 10 cum. biogas plant working on banana stem only. The work is also in progress on erecting a similar plant working on water hyacinth and using other agricultural wastes.

The Institute has also undertaken a project sponsored by Department of Science and Technology for the work relating to biogas production from banana in the scale up of a bench scale experiment and in thermophilic range of temperatures.

Extension Work

The Institue has successfully erected an experiment-cum-demonstration solar hot water system in a textile mill at Ahmedabad from a grant made

available by the Department of Industries, Govt. of Gujarat. The monitoring of the above system would be also undertaken by the Institute. Other important projects undertaken by the Institute is surveying, monitoring and servicing of solar cookers.

Current Projects

No.	Project	Funded by	Amount
1.	Biogas Research Project.	Jyoti Ltd Baroda	Rs. 45,000
2.	Study of Parameters for Optimum Generation of Methane from Plant and Animal Wastes.	"	Rs. 60,000
3.	Study of Parameters for Optimum Selective Coating Properties for Black Nickel and Black Chrome Surfaces.	"	Rs. 20,000
4.	Solar Hot Air Drying of Agricultural Products and Casein.	"	Rs.1,20,000
5.	Electro deposited Black Nickel and Black Chromium: Selctive Coatings.	"	Rs.1,40,000
6.	Energy Needs of Agriculture Development of Renewable Sources: Water pumping Windmills, Photovoltaic pumps and Biogas Plants run on Agricultural Wastes.	Bhailal Amil Foundation, Baroda	Rs.3,50,000
7.	Experimental-cum-demonstration Solar Hot Water System in a Textile Mill.	Director of Industries, Gujarat State	Rs. 80,000
8.	Monitoring of the above Project.	"	Rs. 38,000
9.	Biogas Production from Banana in the Scale-up of Bench-Scale Experiment and in Thermophilic Range of Temperatures.	Dept. of Science & Technology Govt. of India,	Rs.1,68,000
10.	Surveying, Monitoring and Servicing of Solar Cookers.	Gujarat Energy Development Agency, Baroda.	Rs.1,50,000

Laboratory and Test Facilities

1. Meteorological Station : For collecting daily insolation and other climatic data.

2. Direct solar : Hot water system with flat plate collector as well as concentratic collectors, Winston collector, solar greenhouse, hot air system, solar cooker-oven type and paraboloid type, water stills.

3. Wind Energy : Wind tunnels (suction type & blower type) for testing models of different shapes of wind generators.

4. Electrodeposition : For use of selective coating of different surfaces.

5. Bio-conversion : For investigation in the area of biogas production using both animal waste as well as agriculture wastes which include gas chromatograph, calorimeter, muffle furnace, hot air ovens, etc.

Educational Programmes

Two semester elective course on Alternate Energy Sources was introduced at the final year level from the year 1979-80. The Institute also started one year Post Graduate Diploma Course on Solar Energy Systems. In order to bring multi-disciplinary approach to the course, the admission requirements have been made such that any Post-Graduate in Science with subjects of Physics, Chemistry and Biology, or any Agricultural Graduate or any Engineering Graduate is eligible for admission. Each of the students is paid stipend of Rs.400/- from the Institution's Funds.

Plans for future work

It is proposed to take up the following additional work in:

- Demonstration of hot water and distilled water system for a hospital.
- Biogas generation from eucalypitus leaves.
- Design and fabrication of 5 ton cold storage plant.

Communicated by : Dr. R.M. Dave, Hon. Director, Jyoti Solar Energy Institute, P.B. 20 Vallabh Vidyanagar, Kaira, Gujarat 388 120.

MURUGAPPA CHETTIAR RESEARCH CENTRE

Madras 600 042

One of the major activities of the centre is research on renewable energy resources with emphasis laid on bio-conversion methods and processes. For this purpose, the centre presently runs two divisions: (1) Photosynthesis and Energy Division (2) Algal Division. Some of the activities of the centre are summarised below.

Algal Research

Algae collected from local canals, ponds, sewage tanks and soil are examined microscopically. In order to study species, the organisms are cultivated without other forms being present. Depending upon the organisms to be studied, the composition of the medium is altered so as to provide the optimum growth requirements for the desired organisms, whereby growth of other soil forms can be checked.

Spirogyra and Chlorella were predominant in the sample collected from the canal, while Anabaena and Chlorella were abounding in the sewage collected from Ambathur. Samples collected from local ponds and soils showed prevalence of Oscillatoria and Chlorella. Culture collections were also made from different parts of India for various experiments but emphasis is given for local isolates as they can thrive well in the local conditions.

For large scale cultivation of Algae, various pond designs are constructed for investigation, using locally available materials and unskilled labour. Precipitation of the nutrient chemicals water loss due to absorption by bricks/soil cement etc were the problems encountered. So, ponds with just alkathene sheet (1000 g) over clay-bund were constructed and operated with extra care, which eliminated the above problems. Weather permitting, these ponds are used to grow alga, Spirulina Platensis. Attempts are made on "Gley" Ponds. "Gley" is a bipolymer formed by compacting dung or manure mixed with fibrous matter e.g. casuarina roots. It is a natural bipolymer that prevents seepage.

Laboratory studies have been carried out using different media composition with a view to utilise cheaper raw materials for Spirulina cultivation. These newer nutrient media include (a) sea water in varying composition (b) crude sea-salt (c) biogas plant effluent (using cowdung substrate) and (d) "Nutrient bag" method.

A project carried out by the centre was to conduct feasibility study and to set up a pilot facility to produce 1 tonne per day of food or fertiliser grade algae dry mass using the waste materials and energy of large power plants. This proposal has outlined one way by which pre-industrial man can use the wastes of industrial man to make a post-industrial product.

Solar Drier

With "chicken mesh", cement, sand and polythene paper (transparent) a solar drier was made for drying algae and other vegetables. The ferro-cement tray of 1.9m x 1.3m x 0.15m formed the base. On a bright sunny day the tray-air temperature reaches 82°C, while the insulation keeps the temperature at about 70°C even at 5.00 p.m., when the sun is down. The drier has been used for drying paddy, chillies etc. Cost of making 1 Sq.m = Rs.92/- with the total cost for the dimensions mentioned above being Rs.225/-.

As chicken mesh and iron rods were found to be expensive, a new design with bamboo platches, cement and sand was tried. The drying efficiency of this drier was equivalent to that mentioned above, while cost being considerably reduced to Rs.90/- for an overall dimension unit of 1.7 m x 0.7 m., which works to about Rs.70/- per sq.m. Further, attempts were made to improve the risk of breakage due to its bulk to and heaviness. As a resut, a 3.56 m 1.62 m x 0.18 m unit was built at a total cost of Rs.365/- amounting to Rs.64/- per Sq.m.

The aforesaid solar driers reached the maximum temperature between 75°C to 85°C. In these driers, vegetables and chillies were dried. However, when fish drying was attempted, the fish got cooked rather than drying due to intense heat. So as to have the proper drying effect, with suitable

modifications a tent drier has been made. The drier reached the temperature between 45°C to 55°C. The cost for 4 m x 1.5 m unit worked out to Rs.105/-.

Yet another drier for drying paddy was made, which reached temperatures of 45°C to 54°C. Unlike the fish drier, just the mud floor coated with cowdung will be sufficient and there is no need for a raised platform. Total cost of construction was Rs.110/- for a 4 m x 1.5 m unit, which amounts to Rs.18.30 per sq. m.

Materials successfully dried in the above driers are:

1.	Algal biomass	:	2 - 3 hours
2.	Brine soaked okra	:	4 hours
3.	Red Chillies	:	4 hours
4.	Potato Chips (in brine)	:	6 hours
5.	Harvested paddy	:	2 hours
6.	Parboiled paddy	:	3 hours
7.	Fish	:	3 - 4 hours
8.	Snake gourd chips	:	3 hours

All of these retained taste and flavour

Solar Cookers:

Solar cookers were needed to subject algae and other green matter like water hyacinth to high temperature, to help sterilize the biomass by breaking the cell-wall. Large box-type cookers (1 m x 1 m x 0.45 m) were made of jungle - wood planks. Performance of the cookers which reached 120°C were found satisfactory, with Dal and Rice being cooked in about 1½ - 2 hours. Cost with saw dust insulation was Rs.257 and with mineral wood (Lloyd's) insulation Rs.330/-. In both cases, two reeded glass covers were placed cross wise.

Biogas Plants:

MCRC has designed and constructed a biogas plant at their site using locally available materials. A noted feature of this plant is that the design

allows the use of PVC sheet, held by Nylon thread, forming a half Geodesic dome for the gas holder, instead of the conventional gas holder made of mild steel. Known as "Viny-balloon biogas plant", its successful operation has helped to install two more or its' kind in the neighbouring villages. The effluent is useful for algal cultures. By using translucent domes, it is intended to culture photosynthetic bacteria costing almost half the price of current biogas conventional plants. It is felt that further improvements are possible. A community biogas plant, also using PVC is being constructed.

Energy Plantations:

"A case study for the Coromandel Littoral" carried out by the Centre is about intense cultivation of casuarina trees (Latin: Casuarina equisetifolia) for generating 100 MWe (installed 160 MWe) in a power plant. Using the cultural practices of four different areas in Tamil Nadu, costs and energy calculations have been carried out. The calculations account for continuous harvesting.

It is said that casuarina tree grows all over the Deccan Peninsula; in particular it grows on ocean beaches all over the South. It will grow without much attention or much water. Using the method explained and depending upon certain investment decisions, the plantation will pay back all capital and other costs in periods varying from 5 - 30 years. At the end of the larger periods, land becomes wholly owned by the plantation. Ecologically these plantations are far more desirable than present thermal power plants, with favourable energy returns. These plantations offer a way to generate small amounts of decentralised power for rural use.

Wind Energy Devices:

The centre has designed and developed an award winning invention of low-cost windmills for pumping water, known and "ANILA-1", for coastal locations. It can be fabricated from local materials, by local artisans at an estimated cost of Rs.1,500. Anila-1 can deliver 2,000 litres of water per hour at a total lift of 8 metres in 25 km/hr wind and can work for at least 12

hr/day, non-stop. At least five of these windmills, installed in villages near Madras, are at present working satisfactorily. Anila-1 is giving new way to the genesis of Anila-2 and Anila-3, now in progress.

Other wind devices attempted are "Wind agitators" for agitation of the algal ponds, pumping algal culture from one pond to the other etc. A vertical axis savonius rotor (made of a 200 lit oil drum) is held by a casuarine shaft to agitate a circular pond. This device costs about Rs.95/- including labour cost. Also attempted are hand agitation and agitation by pumping. "Tree Power" harnessing has been an important philosophy of the centre.

New areas of work by the Centre are Biodynamic gardening, Hydroponics, Fish ensilage, Pisciculture, Cultivation of Photosynthetic bacteria and Integrated Systems. Laboratory facilities and human expertise is gradually being built up. The centre also publishes periodical technical notes in the interests of dissemination of information and to interact with other groups working in the area of low-cost technology.

Prepared from the published technical reports of Shri. A.M.M. Murugappa Chettiar Research Centre, Tharamani, Madras 600 042.

NATIONAL CHEMICAL LABORATORY

Pune

National Chemical Laboratory was established in 1950 to undertake time-targeted product oriented research with the object of import substitution, export promotion and industrial production by making use of indigenous natural resources and by-products available from agricultural and other industries. Fields of research include bio-chemistry, chemical engineering, inorganic chemistry, organic chemistry, physical chemistry and polymer chemistry. Research on solar energy commenced during August 1977.

Solar thermal utilisation

In the area of solar thermal utilisation, the process for making selective absorber coatings of chromium-black by cathodic deposition and copper-black with anodic oxidation have been standardised and their optical and structural properties studied. In another related development tin oxide coated glass with 85% transmittance for visible radiation and 80% reflectance in IR region with cut-off at 1.7 to 1.8 has been developed. It is claimed that, the process employed, is suitable for large area deposition as it uses a simple chemical vapour deposition technique.

Photovoltaics

During 1980-81, the Laboratory successfully developed a new type of "spin-on" composition to dope boron in silicon. This is used as the dopant for silicon in solar cell fabrication. The "spin-on" technique is the latest improvement in the technology for doping of semi-conductors which overcomes the limitations of the other known doping processes. In this process a uniform oxide layer containing the dopant ions is formed simply by putting a drop of this material on the semiconductor surface and then spinning the semiconductor crystal to get a thin uniform layer. Dopant ions get diffused into the semi-conductor on heating to give the necessary concentration and depth profile.

One of the main areas of future research is the production of solar grade silicon at a cost of Rs.100/- per kg. This work will be carried out during 1981-83. Also, work on suitability of molybdenum-black and cobalt-black as selective surfaces will be undertaken. Another area of research aimed at solar thermal utilisation is to try out a liquid solar absorber. The attractive feature of this approach is that the absorbing liquid has the required solar selectivity and is itself used as a heat transfer medium thereby reducing the number of steps involved and consequently reducing the thermal losses.

Since July 1978, a project on preparation of ultrapure poly-crystalline silicon, (sponsored by M/s. Grindwell Norton Ltd., Bangalore), is in progress. Under this project, standardisation of conditions for cracking of trichlorosilane to silicon (in a quartz tube with maximum possible conversion efficiency) was achieved. Future work involves the study of kinetics, thermodynamics, power requirements, purity and economy of the process.

Biomass

Another interesting project funded by CSIR since April 1979, aims at catalytic conversion of alcohol from biomass into fuels and petro-chemicals. Seven patents have been filed for the manufacture of catalysts and catalytic processes for the conversion of rectified spirit and products derived from it into fuels like gasoline and other petro-chemicals. Also, an agreement is being signed with ACC, Bombay, for the manufacture of catalysts and joint offer of processes based on it.

Also, funded by CSIR since April 1974, is a project for protein food/energy from cellulosic materials. Microbial strains have been identified and conditions of fermentation standardised to produce cellulolytic enzymes in submerged culture. Optimisation of process conditions in instrument controlled fermentors and use of the enzymes cellulose saccharification are in progress. Microbial biomass protein production from pretreated rice straw by a fungal fermentation has also been developed on a laboratory scale.

Publications

1. M.C. Srinivasan. Cellulose, a source of single cell protein production. Chemical Industry Developments, 11, 1977, 26-30.

2. M.C. Srinivasan, and others.
Utilisation of cellulose for the production of glucose and single cell protein.
Hindustan Antibiotics Bulletin, 19, 1977, 31-36.

3. K.B. Bastawade, and others.
Cellulolytic enzymes of a penicillin strain.
Proc. Bioconversion Symp. IIT (Delhi), 1977, 143-51.

4. K.B. Bastawade, and others.
Enzyme hydrolysis of cellulose.
Proc. Bioconversion Symp. 117, Delhi, 1977, 387-395.

5. M.C. Srinivasan, and V. Jagannathan.
Utilisation of cellulose by fermentation proceedings of the Symposium on "Perspectives in Industrial Microbiology, 1978, 30-37.

6. V.V. Deshpande, and others.
Single cell protein from cellulosic materials.
Proc. Industrial Fermentation Symposium R.R.L. Jammu 1978, 119-130.

7. V.V. Deshpande, and others.
Utilisation of cellulosic waste for energy production.
Reg. J. Energy Heat Mass Transfer 2, 1980, 23-29.

8. M. Vaidya, and others.
Purification and properties of endo and exoglucanases of Fusarium lini
Paper presented at the 2nd International Symposium on Bioconversion and Biochemical Engineering, IIT, Delhi, March 1980.

9. Lakshmikantham, B.C.
Purification and properties of B-glucosidase of Penicillium funiculosum.
Paper presented at the 2nd International Symposium on Bioconversion and Biochemical Engineering, IIT, Delhi, March 1980.

10. J.G. Shewale and J.C. Sadana.
Cellulase and B-glucosidase production by a basidomycete sp.
Can. J. Microbiol. 24, 1978, 1204-1216.

11. J.G. Shewale and J.C. Sadana.
Enzymatic hydrolysis of cellulosic materials by S. rolfsii culrue filtrate for sugar production.
Can. J. Microbiol. 25, 1979, 773-783.

12. J.C. Sadana, A.H. Lachke and J.G. Shewale.
Biochemistry of cellulose degradation and cellulose utilization for feeds and for protein.
J. Sci. and Ind. Res. 38, 1979, 442-453.

13. J.C. Sadana, J.G. Shewale and M.V. Deshpande.
Enhanced cellulase production by a mutant of Sclerotium rolfsii.
Appl Environ Microbiol. 38, 4, 1979, 730-733.

14. J.C. Sadana, J.G. Shewale and M.V. Deshpande.
High cellobiase and xylanase production by S. rolfsii UV - 8 mutant in submerged culture.
Appl Environ Microbiol. 39, 4, 1979, 935-936.

15. J.C. Sadana, J.G. Shewale and M.V. Deshpande.
Enzymatic hydrolysis of cellulosic materials by S. rolfsii UV - 8 mutant culture filtrate.
Proc. 2nd International Symp. on Bioconversion and Biochemical Engineering, IIT, New Delhi, 1980.

Communicated by : Dr. S.H. Iqbal, Head, Div. of Tech. Services, National Chemical Laboratory, Pune 411 008.

NATIONAL DAIRY RESEARCH INSTITUTE

Southern Regional Station

Bangalore

A research project on 'Development of Solar Driers' was started in early 1979 with the objective to develop alternate technology applicable in rural areas based on solar energy for drying straw. The project was sponsored by the Indian Council of Agricultural Research, New Delhi. The project was completed in 1980.

The technical programme framed was the development of simple models with locally available materials of construction; evaluation of working efficiency of the models with varying types of materials of construction; evaluation of efficiency of drying of different materials like straw.

A rural application type solar drier was fabricated with locally available cheap building materials such as casurina poles, wooden rafters, a.c. pipe, expanded metal, etc. The south oriented drier unit has an air inlet vent of about 0.7 m^2, collector area of 17.28 m^2 and the volume of the drying chamber was 0.9 m^3.

Fodder varieties such as Lucerne (Medicago Sativa), Rhodes grass (Chloris gayana), Paragrass (Brachiaria mutica), Guinea grass (Panicum maximum) and Maize (Zea Mayz) were dried in the unit with parallel sundrying control experiments for comparison.

Steps are being taken for setting up the solar laboratory for which the proposal includes equipping the following :

1. Surya mapi - CEL,
   120 mw/cm^2, 4 configuration.
2. Milliammeters, milli voltmeters and multimeters.
3. Pyronometer - LINKE - FENSSNER.
4. Pyrheliometer - P.J. Kipp & Zonen, Holland.

5. Solar cells modules - CEL.
6. Encapsulated solar cells, solar cell panels - CEL.
7. Nickel - cadmium rechargeble batteries.
8. Filters - Normal, overcast and of wave lengths from 300 - 800.

Development of solar collector array is envisaged for generating thermal energy required for dairy plant operations.

Publications

1. Performance study of solar drier suitable for rural application by M.S. Venkataramaiah and E.G. Jagannath. Presented at National Solar Energy Convention held at Annamalainagar, Dec. 1980.

2. Feasibility study of harnessing solar energy for cooling milk in farms by M.S. Venkataramaiah and E.G. Jagannath. (To be published)

3. Functional characteristics of solar fruit driers by M.S. Venkataramaiah and E.G. Jagannath. (To be published)

Communicated by : Mr. M.S. Venkataramaiah, National Dairy Research Institute, Scuthern Regional Station, Adugodi, Bangalore 560 030.

NATIONAL PHYSICAL LABORATORY
New Delhi 110 012.

National Physical Laboratory (NPL) is one of the foremost institutions in the country to have tried utilising solar energy, as early as in 1950's. A solar water heater developed by the institute then, employed corrugated, galvanised iron-sheet collectors which was coupled to a 140-liter storage tank. Some of the recent projects carried out by the institute are described below.

Flat Plate Collectors

The physics of the flat plate collectors particularly their nature and the role of selective coatings on absorber plate, the distribution and geometry of the channels trough which energy collection fluid is circulated; nature thickness of edge and back insulation have been theoretically investigated.

While pursuing research on selective coatings, various combinations of metals embedded in dielectrics have been tried. electroplated black nickel, black chrome etc., under various conditions of plating were studied for reflectivity in the entire spectral region (0.3 u to 25 u), total emission at various temperatures, microstructure, x-ray diffraction etc. Black chrome and black nickel films are a mixture of the total particles embedded in their corresponding oxides. A correlation is found to exist between microstructure and the optical behaviour cannot be explained on Maxwell-garnett theory. Rectangular grids and complementary structures were also investigated for their optical properties. It appears that properly structured films would give better selectivity. Holographic techniques are being tried to produce structured films. Effects of heat treatment on these films has also been investigated. A few collectors using selective coated absorbers have been made for field evaluation.

Concentrating Collectors

Attempts have been made to develop cylindrical parabolic concentracto: collectors. Early efforts to mould a metal sheet into a cylindrical parabola and

to alluminise it for high reflectivity did not give desired results in view of the high r.m.s. deviation from the true parabolic cylinder. Techniques have now been developed to make glass parabolic cylinders. These glass cylindrical parabolas have very good surface finish and can be alluminised on the back to give a sharp focus. The electronic tracking system coupled to these cylindrical parabola has been made and stagnation temperatures of nearly 400°C have been obtained.

Collector Testing Facility

In order to determine the performance of a solar collector, specifications of the materials that constitute it, need to be known. These are (a) transmission and reflectance of glass cover over the entire spectral range. (b) absorptance and emittance of the absorber plate (c) thermal conductivity of the insulating materials. Facilities for testing all these parameters have been set up.

A set rig to test the thermal performance of a solar collector based on the NBS document is being set up. A variety of test procedures suggested by NBS, ASHRAE, German Study Group, Dr. Tabor have been analysed and a test procedure for compartive evaluation of the collectors have been suggested. Indoor test rig using solar simulator is being set up.

Rankine Cycle Engines

An organic vapour Rankine cycle engine using freon 114 has been developed. Two systems are under trial. In one, flat plate collectors are made to provide temperature of about 90°C. The hot collector will exchange heat with low boiling point organic liquid to generate high pressure vapour. These high pressure vapours drive a prime mover to generate mechanical power, on the shaft. A critical analysis of the reciprocating system, turbine and positive displacement rotary machines has suggested to use of positive displacement machine. Spiral expanders of various capacities have been made and tested. A prototype of 1 kW solar pump was made and has been in operation for the last few months. An engineered model of this pump is being fabricated.

In another system, cylindrical parabolic concentrators are used to generate steam at 180°C and then to drive a spiral expander. The system is under fabrication. Possibility of using these mechanical energy convertors to produce refrigeration using vapour compression system is being worked out.

CdS-Cu_2 Solar Cells

The electro-optical properties of evaporated CdS thin films doped and undoped have been investigated. Similarly, the structural and electrical behaviour of Cu_2 films prepared by vacuum evaporation of substrates at various temperatures has been investigated. Using the knowledge gained in these investigations, a few solar cells have been fabricated. A test facility to test solar cell panels is being set up.

Prepared from the published information available at the Tata Energy Research Institute, Documentation Centre, Bombay.

REGIONAL RESEARCH LABORATORY

Trivandrum

The Regional Research Laboratory, Trivandrum is a regional resource-cum-need based R&D institution. An Energy Group was set up in the middle of 1979, in the Materials, Glass and Ceramics Division, to promote R&D activities in the areas of renewable energy resources. A Project was undertaken on the utilisation of solar energy for low and high temperature applications in the agricultural and industrial sectors of Kerala. The contributions made to date under this project include the design, development, fabrication, erection and testing of a solar furnace for possible use in metallurgical and ceramics industries. The solar furnace is based on a 3 metre mirror facetted parabolic concentrator and has successfully been used for melting and casting of zinc, lead, tin and their alloys. A heat transfer analysis of this solar furnace has also been made with a view to streamline the design procedures and also to aid in performance optimisation studies. Recently, of heat exchanger unit has been designed for the production of process steam and hot air for drying and preheating uses in ceramics industries.

Regarding the low temperature applications of solar energy, an important aspect of the study is concerned with the drying of plantation products of Kerala. A solar drier comprising of a $6m^2$ collector and capable of drying about 500 coconut splits per batch has been designed and fabricated. This drier can also be used for the drying of spices such as pepper, cardamon, etc.

In addition to these, demonstration models of basket type solar cooker, solar water heater and solar still have been installed and their performances have been monitored under a variety of operating conditions. The performance characteristics of the solar cooker, as monitored during the cooking of cassava tuber under different conditions have been compared with those obtained from a heat transfer analysis. Factors contributing to the cooker effeciency have been identified and methods of improving the cooker effeciency have been looked into.

At present, the project team consists of two materials scientists, two solid state physicists, a mechanical and an electrical engineer. Inhouse facilities available for the project at present include radiation measuring instruments and fabrication workshop. These facilities are now in the process of upgrading and expansion to meet the future requirements of the project which include development of solar furnaces for higher temperatures, automated tracking systems, etc.

List of Publications

1. "Solar furnace - a heat transfer analysis" by V. John, M.R. Madhava, D. Suresh, S. Seshan and P.K. Rohatgi. Proc. 5th National Heat and Mass Transfer Conference, Hyderabad, 13-16, Feb. 1980.

2. "Solar drying" by P. Mohanan, V. John, M.R. Madhava and P.K. Rohatgi. Proc Seminar on Applications of Solar Energy, Institution of Engineers, Trivandrum, 1 May, 1980.

3. "High temperature applications of solar energy" by V. John, P. Mohanan, M.R. Madhava and P.K. Rohatgi. Proc. Seminar on Applications of Solar Energy, Institutions of Engineers, Trivandrum, 1 May, 1980.

4. "Solar drying of spices" by M.R. Madhava, V. John, P. Mohanan, P.P. Thomas, A.G. Mathew and P.K. Rohatgi. Proc. I. Annual Workshop on Agricultural Engineering and Technology in Kerala, Trichur, 28-29 May, 1980.

5. "Solar furnace for metallurgical applications" by V. John, P. Mohanan, M.R. Madhava and P.K. Rohatgi.Urja - A Journal of Energy, June 1980.

6. "High temperature uses of solar energy" by V. John, M.R. Madhava and P.K. Rohatgi. Proc. Seminar on Non-conventional Energy Sources, Institution of Engineers, Trivandrum, 1 Sept., 1980.

Communicated by : Prof. P.K. Rohatgi, Director, Regional Research Laboratory, Industrial Estate P.O., Trivandrum 695 019.

SOLIDSTATE PHYSICS LABORATORY

Delhi

Solidstate Physics Laboratory, Delhi has successfully developed silicon solar cells for space applications. The solar cell group at SSPL has been actively engaged in this field since 1974 and has a close interaction with ISRO Satellite Centre, Bangalore.

Starting from FZ, boron-doped, 10 ohm-cm, polished, single crystal silicon slices, the n+-diffused region is created by using conventional diffusion techniques using $POCL_3$ as a source. The junction depths are in the range 0.3-0.4 microns. Aluminium is evaporated on the back and the parasitic n+-region is punched through to form a p+-layer at the back. Ti-Pd-Ag contact system is incorporated for the front and back by sequentially evaporating Ti, Pd and Ag. Photolithography technique is adopted to delineate the grids to maintain a strict control over the covered area to less than 10%. Slices are sintered at 550°C in forming a gas ambient to provide a low-resistance ohmic contact. The slices are then scribed and diced into squares of 2 x 2 cm^2. An anti-reflection coating of TiO_x is provided by evaporating TiO in an oxygen ambient. This is subjected to a low-temperature heat treatment with a view to decrease the absorption of the layer. The cells are then tested for their electrical and optical performance. The cell characteristics are as follows:- Open Circuit Voltage : 540-550 mV, Short Circuit Current : 125-135mA, Pm : 55-60 mW and Curve Fill Factor : 0.75-0.80. Cells with an yield aroud 50% have been fabricated.

About 300 solar cells have been supplied to ISAC, Bangalore. A panel of SPL-fabricated solar cells was flown on board the second Indian setellite, 'BHASKARA' launched in June 1979 with a view to space qualify the cells. The periodically obtained telemetric data from the panel during about 1000 orbits of the satellite round the earth demonstrated that the performance of the panel was comparable with that of a panel of imported cells.

The solar cell group at SSPL is actively engaged in improving performance of the cells by using such techniques as texturisation and improved anti-reflection coatings such as Ta_2O_5. Initial results on both these fronts have been very encouraging. Plans to incorporate back surface field, back surface reflection, and shall ower junctions are under active investigation. In addition work is in progress to fabricate 2 x 4 cm^2 solar cells to facilitate solar cell panel design.

Communicated by: The Director, Solid State Physics Laboratory, Lucknow Road, New Delhi 110 007.

TATA ENERGY RESEARCH INSTITUTE

New Delhi

Tata Energy Research Institute (TERI) is the response of the House of Tatas to the energy crisis looming at large. The Institute, was founded in 1974 with its registered office at New Delhi.

At its formative stage it was realised by TERI that considerable time is necessary to build its own facilities for research. To ensure a quick take - off and make use of the available funds, TERI sought the advice of eminent scientists in the country and decided to sponsor research programmes, until its own facilities are ready. TERI is a non-profit organisation.

In the broadest terms, the scientific research programmes, as embodied in the Objects Clause of the Institute, comprises of:

1. Research, development, demonstration and application of non-depleting and non-polluting sources of energy;

2. Research, development, demonstration and application of techniques which will ensure more efficient, and less polluting, utilisation of the country's finite sources of fossil and/or fissile fuels; and

3. Environmental and ecological implication of increasing energy production and consumptions.

The Institute is at present sponsoring and supporting programmes at various institutions in the country, with new impetus on energy conservation, solar, wind, animal and biomass energies. As on date more than 60 projects in these areas have been sponsored as outlined below:

Energy Policy:

1. Technology forecasting of energy systems for India until the year 2000 - Indian Institute of Science, Bangalore 560 012. (Completed)

Energy Conservation:

2. Energy conservation in domestic combustion - Punjab Agricultural University, Ludhiana 141 004.

3. Energy saving in textile wet processing by process modification and re-using heat energy at various points - Bombay Textile Research Association, Bombay 400 086.

4. Studies of Gasification of Coal Fluidised Bed - Central Mechanical Engineering Research Institute, Durgapur 713 209.

5. Study on conservation of light diesel oil used in pump sets for lift irrigation in Gujrat State - Institute of Cooperative Management, Ahmedabad 380 006.

6. Techno-economic study of substitution of steel and other heavy alloys in transportation equipment to conserve energy - Indian Institute of Science, Bangalore 560 012. (Completed)

7. Techno-economic study of the use of cogeneration in main Industries - NITIE - Bombay 400 087.

Energy and Community :

8. A study of bullock carts - Indian Institute of Science, Bangalore 560 012.

9. Cooking with choolahs - a survey in Bhavnagar area - Central Salt & Marine Chemicals Research Institute, Bhavnagar 364 002.

10. Energy and rural settlements - Indian Institute of Science, Bangalore 560 012.

11. Energy balance and utilization of agricultural waste in a farm - Punjab Agricultural University, Ludhiana 141 004.

12. Energy in the paddy-rice handling and storage system - Punjab Agricultural University, Ludhiana 141 004.

13. Experimental and analytical evaluation of the techno - economic feasibility of the Humphrey pump of lift irrigation - Indian Institute of Science, Bangalore 560 012.

14. Study of energy plans and flows in five typical villages of Andhra Pradesh - Administrative Staff College of India, Hyderabad 500 475.

15. Survey of energy use pattern on the farm of five villages in Northern India - Punjab Agricultural University, Ludhiana 141 004.

Solar Collectors and Collector Systems:

16. Construction of a stationary spherical reflector for rural use - DATAG, Auroville 605 101.

17. Design and feasibility study for fabrication of a solar energy concentrator using stretched skin - Radio Astronomy Centre, Tata Institute of Fundamental Research, Oatacamund 643 001.

18 Development of a solar concentrator and a hot air engine - Central Salt & Marine Chemicals Research Institute, Bhavnagar 364 002.

19. Development of an inexpensive augmented integrated solar collector and storage system for agricultural requirements - Indian Institute of Technology, New Delhi 110 029.

20 Development of honey-comb solar collectors - Central salt & Marine Chemicals Research Institute, Bhavnagar 364 002.

21. Development of production techniques for plastic fresnel lenses - Indian Institute of Technology, Bombay 400 076.

22. Developing of tracking system for solar concentrators - Indian Institute of Science, Bangalore 560 012.

23. Fabrication and testing of full scale working prototypes of solar furnace for metallurgical uses - Indian Institute of Science, Bangalore 560 012.

24. Low cost selective surface for efficient solar applications - Indian Institute of Technology, New Delhi 110 029.

25. Techno-economic feasibility studies of solar furnaces for metallurgical uses - Indian Institute of Science, Bangalore - 560 012.

Thermal Storage Systems:

26. Development of an active heat exchanger for latent heat thermal energy storage - Punjab University, Chandigarh 160 014.

27. Development of an energy storage system based on reciprocal salt pairs for multiple applications - Punjab University, Chandigarh 160 014.

28. Thermochemical systems for storage and reuse of solar energy for domestic applications - Regional Engineering College, Warangal 506 004.

Space Heating and Cooling:

29. Natural heating and cooling of buildings in Northern India - Punjab Agricultural University, Ludhiana 141 004.

30. Nocturnal radiation water cooler cum solar water heater - Indian Institute of Technology, Kanpur 208 016.

31. Studies on comfort, conditioning of middle class houses in India - Thaper Institute of Engineering & Technology, Patiala 147 001.

32. Zero energy home in the semi-arid-zone - Birla Institute of Technology and Science, Pilani 333 031.

Solar Application Devices:

33. A reciprocating device using solar energy - Delhi College of Engineering, Delhi 110 006.

34. Absorption of solar radiations by water in presence of dyes in solar stills - Jawaharlal Nehru University, New Delhi 110 067.

35. Application of a heat pipe in solar cooker - Delhi College of Engineering, Delhi 110 006.

36. Demonstration of use of earth still for afforestation in arid zones and to obtain potable water from brackish water - C.C. Shroff Research Institute, Bombay 400 062.

37. Development of solar devices for production of low temperature for preservation of food stuffs and other materials - Central Salt & Marine Chemicals Research Institute, Bhavanagar 364 002.

38. Solar seed irradiator and seed roaster - Central Salt & Marine Chemicals Research Institute, Bhavnagar 364 002.

39. Utilisation of solar energy for pumping water using Minto wheel - Delhi College of Engineering, Delhi 110 006.

Photovoltaics and Photogalvanics:

40. Development of a pump using silicon/CdS solar cells - National Physical Laboratory, New Delhi 110 012.

41. Fabrication of CdS solar cells - Jadavpur University, Calcutta 700 032.

42. Fabrication of large size solar cells - Jadavpur University, Calcutta 700 032.

43. Study of solar photochemical galvanic cell - Indian Institute of Technology, Bombay 400 076.

44. Thin film SIS solar cells - Indian Institute of Technology, New Delhi - 110 029.

Biomass:

45. All India coordinated project on algae - Indian Agricultural Research Institute, New Delhi 110 012. (Completed)

46. Assessment of sugar cane as energy crop in Punjab - Punjab Agricultural University, Ludhiana 141 004. (Completed)

47. Eco-Farm Project - Progressive Education Association, Wardha 442 001.

48. Energy from agricultural residues - a thermodynamic evaluation - Punjab Agricultural University, Ludhiana 141 004.

49. Kenaf for fuel plantation - Learners' Centre, Goa 403 506.

50. Utilisation of agricultural wastes in a village community - Punjab Agricultural University, Ludhiana 141 004.

Biogas Technology:

51. Anaerobic digestion of municipal solid wastes - National Environmental Engineering Research Institute, Nagpur 20.

52. Bio-management of aquatic and terrestrial weeds and their use as biogas plant, feed, fertilizer, animal feed, protein and fibre source and waste water treatment - C.C. Shroff Research Institute, Bombay 400 062.

53. Development of biogas technology - Indian Institute of Science, Bangalore 560 012. (Completed)

54. Further studies on biogas technology - Indian Institute of Science, Bangalore 650 012.

Wind Energy:

55. Design fabrication and performance evaluation of vortex windmill - Indian Institute of Technology, Bombay 400 074.

56. Development of a low-cost windmill and irrigation pump - Indian Institute of Science, Bangalore 560 012. (Completed)

57. Development of windmills - Indian Institute of Science, Bangalore - 560 012.

58. Wind energy development programme - Development of Alternative Technology in Auroville Group, Pondicherry 650 101.

TERI Field Research Unit

TERI is operating a field research unit at Pondicherry since 1975. Over the last six years it has built up its capabilities and strengthened its competance in renewable energies. It is now successfully demonstrating field projects and offering high quality consultancy services.

Projects undergoing research at the Field Research Unit are:

1. Medium temperature solar collectors for liquids.(Plus solar pond)
2. Convective solar dryers for agro-industrial products.
3. Community planning using renewable energy sources.
4. Rural energy needs and systems.(Includes solid fuel cooking stoves)
5. Ladakh solar passive building project - In Association with Intermediate Technology Industrial Services, ITDG, England.
6. Retrofitting passive heating systems in childrens' dormitory at the SOS Tibetan childrens' village, Leh.

TERI Documentation Centre

Recognising the felt need and lack of information existing within the country, TERI established an Energy Documentation Centre in 1975. Over the years, the centre has build-up a sound energy information infrastructure and is rendering numerous information services both within the country and overseas. While facilitating communication of energy ideas within the country, it has simultaneously formed a feeder to similar international systems. It is currently operating a project jointly sponsored by TERI and Unesco, Paris to strengthen the information infrastructure development in three specific areas namely, Solid fuel cooking stoves, Water pumping windmills and Biogas technology.

Tata Energy Research Institute encourages all activities to develop a strong energy resource base in the country. It has provided financial assistance for writing noteworthy publications, organising as well as participating in seminars, symposia and workshops. TERI welcomes research project proposals within its broad framework of objectives. Further details could be obtained by writing to the Research Coordinator, Tata Energy Research Institute, Bombay House, 24 Homi Mody Street, Bombay 400 023.

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Ootacamund

Design and feasibility study for the fabrication of a solar energy concentrator using stretched skin was undertaken for developing an economical, linear solar energy concentrator suitable for mid temperature (200-300 °C) applications. The study is for assessing the suitability of a novel design of using stretched, thin, steel tapes with reflecting films of aluminised acrylic adhered to them, for constructing a fixed mirror solar concentrator (FMSC). The project commenced in September 1978 and is sponsored by Tata Energy Research Institute. Tata Consulting Engineers, from Bombay are also involved in the project as consultants for the structural, mechanical, thermal and other aspects of the solar collector. Assistance on the aerodynamic and vibration problems of the design is provided by the Indian Institute of Technology, Bombay.

Work done over the past $2\frac{1}{2}$ years has shown that the design is technically feasible and can lead to considerable reduction in the cost of solar reflectors compared with conventional designs. The design is being patented. Extensive theoretical and experimental investigations of the effects of wind-induced vibrations on stretched tapes have led to the development of simple techniques to curtail the vibrations of the reflector surface and to annul the defocussing due to the vibrations. Weathering studies on the aluminised, self adhesive, acrylic reflecting films have shown the effects of weathering to be small.

Encouraged by the above results the construction of a test unit of the FMSC has been undertaken. The fabrication and erection of the unit of 36 m^2 collecting area is in an advanced stage of completion. Optical and thermal performance tests on the test unit would be carried out during 1981. The experience with the test unit is to yield data which would be used for arriving at optimised designs for larger pilot plants/prototypes.

Theoretical studies, supported by computer codes wherever necessary, have been carried out. They deal with intensity profile at the focal line of the FMSC, tracking rates, end illumination losses, steady state analysis of heat transfer at the absorber etc.

Facilities exist for measurements/recording of windspeeds, low level vibrations of stretched tapes, and beam component of solar insolation (Angstrom Pyrheliometer). A test rig for measurement of rate of heat loss of heat receiver assembly (HRA) which is to be used in the test unit of the FMSC is under construction.

Future Work

The follow up of the field on the test unit will comprise : (i) Cost analysis for the test unit and the projections for an optimised design of FMSC modules/arrays with collecting areas of about 250 m^2, (ii) development of better designs for the HRA and fluid loop with the help of computer studies.

Publications

1. Russell's Fixed Mirror Solar Concentrator: Comments on self-shadowing, V. Balasubramanian, ITR No.RAC/SE/78-1.

2. Theoretical Formulation of the Individual Strip Contribution in a Russell's Concentrator. S.G. Sankar, V. Balasubramanian, ITR No. RAC/SE/79-01.

3. Tracking Rate for a Russell's Concentrator at Low Latitudes Located Horizontally with its Long Axis in the N-S Direction, V. Balasubramanian, ITR No. RAC/SE/79-2.

4. Concentrators for Solar Energy Utilization. G. Swarup and V. Balasubramanian, Proceedings of the National Convention in Solar Energy, Bombay, December 1979.

5. Double Magnetic Pick-up Difference Amplifier for Recording Oscillations of Stretched Steel Tapes, V. Balasubramanian, ITR No.RAC/SE/80-01.

6. Thermal Energy Balance for the Absorber. V.R. Balachandran, ITR No. RAC/SE/80-02.

7. Accurate Template-Marking using a Theodolite, V.R. Balachandran, ITR No. RAC/SE/80-03.

8. Endlosses of a N-S Oriented Horizontal FMSC, S.G. Sankar and V. Balasubramanian, ITR No. RAC/SE/80-04.

9. Endlosses of an E-W Oriented FMSC, S.G. Sankar and V. Balasubramanian, ITR No. RAC/SE/80-05.

Communicated by : Dr. V. Balasubramanian, Radio Astronomy Centre, Tata Institute of Fundamental Research, P.O. Box 8, Ootacamund 643 001.

VIKRAM SARABHAI SPACE CENTRE

Trivandrum

The activities concerning renewable energy research and development started during the latter part of 1971 at VSSC. Major activities were centered around the following subjects :

Solar Cells

Vapor deposition of CdS onto Mo substrate followed by a wet chemical process to obtain a thin layer of cuprous sulphide resulted in the required heterojunction of CdS-CuS. Grids are formed by vapour deposition of copper using proper masks. Alternately, copper grids coated with gold are pasted to the cell using conducting cement. Contact leads are taken using silverepoxy conducting cement. Kapton - a polymide plastic film has been tried as substrate material in place of Mo. Cells with an open circuit voltage of 450 mV, and short circuit current of 7 mA/cm^2 has been already obtained. Various parameters that control the life/quality and reliability of the solar cells have also been achieved.

Solar furnace

Inputs for melting of refractory crystals of refractory metals and oxides, thermo-electric factors associated with oxide layers and junctions of oxide layers using concentrated solar energy have been generated. Design of a 1m diameter solar concentrator has been completed.

Solare Energy Absorbing Materials (Seam)

Analysis of the techniques for solar energy conservation have led to the chemical and physical interpretation of the SEAM concept. Software design to utilise special techniques for such SEAM has been generated from the currently available materials processing methods.

On-Going Research projects

Solar Cells :

Improvement on the conversion efficiency of the cells, overall performance of the cells, enhancement of the power to weight ratio by using light weight substrate in place of heavy refractory type metal foils, are some of the ongoing research topics.

Solar Furnaces

Light weight design of the solar furnace with a view to produce portable variety of such alternate sources.

Seam :

Further investigation and design of new materials for the solar energy absorption and conservation in order to utilise the power from the sun.

Laboratory and Testing Facilities :

The laboratory has the following facilities:

vacuum deposition units (2 Nos)
Laboratory oven
Digital multimeter
IMECO ultrasonic cleaner
Tungsten projector lamp set up
Clean room of 37 sq.m.

Scientists/Researchers:

1. Dr. M.K. Mukherjee, Head, Materials Group
2. Dr. B.K. Sarkar, Head, Metallurgy & Ceramics Divn.
3. Dr. T.S. Lakshmanan, Engr. SE
4. Dr. S. Subba Rao, Engr. SE

5. M.J. Nair, Engr. SE
6. S.K. Dutta, Engr. SE
7. M.P.R., Panicker, Engr. SO
8. N.R. Pillai, Engr. SC

Future Programmes/Activities :

The future programme and activities will be more towards solar cells including the SEAM by combination of solar cell and storage batteries for use in remote/rural areas and special applications. For example, emergency lights in surgical operation theatres in hospitals may use storage batteries that can be charged by using solar cells.

Communicated by : Dr. M.K. Mukherjee, Head, Materials Science Division, Vikram Sarabhai Space Centre, Trivandrum.

OTHER RESEARCH INSTITUTIONS

Indian Institute of Tropical Meteorology, (Pune) Field Unit, Bangalore

A solar radiation data handbook project group is functioning at the Bangalore Field Unit of Indian Institute of Tropical Meterorology, Poona.

Sponsored by the Department of Science and Technology and in collaboration with the India Meteorological Department, the Project has its main aim the publications of all available solar and terrestrial radiation data in the form required by solar energy users in India. The project is in 2 parts, the first to publish all observed data, the second to compute data at stations where such data are not measured, using theorectical models and regression formule correlating sunshine and solar radiation.

Part I of the Project was completed and the Handbook of Solar Radiation Data for India was published in December 1980. Part II is expected to be completed by the end of 1981. Communicated By : Dr. (Miss) A. Mani, Raman Research Institute Trust Facility, Bangalore.

Raman Research Institute, Trust Facility, Bangalore

The work of the Instruments Development Unit at the Raman Research Institute Trust Facility is mainly concerned with the development of instruments for the measurement of solar and wind energy.

Techniques for the construction of precision thermoelectric pyranometers for the measurement of global and diffuse solar radiation, thermoelectric pyrheliometers and Angstrom compensation pyrheliometers with readout equipment, and sunshine recorders have been developed and the know-how transferred to National Instruments Limited, Calcutta, who now manufacture these. Electronic integrators with digital counter printers for automatic

integration of the outputs from pyranometers and pyrheliometers to give hourly and daily sums of solar radiation have also been developed. Facilities for the test and calibration of each of the above instruments against national and international standards are available; also facilities for the training of observers and technicians in the measurements of radiation and evaluation of data. Future programmes include the development of improved precision pyranometers for measurement of the solar radiation in specified spectral regions, electric sunshine recorders, pyrgeometers for the measurement of long wave radiation, net pyrradiometers for the measurement of net radiation, etc.

The development of wind instruments for the measurement and recording of instantaneous and average values of windspeed and direction has also been undertaken. The know-how has ben transferred to M/s. Dynacraft Machine Company, Bombay, who now manufacture these. Communicated by : Dr. (Miss) A. Mani, Raman Research Institute Trust Facility, Bangalore.

AUTO SPARE INDUSTRIES

Pondicherry

Research activities in the Energy Division of Auto Spare Industries, were started in 1975. With the available resources, considerable work is possible in the field of harnessing wind energy to meet the water requirements of communities living in nearby villages. The designs evolved here are suitable for the remote areas in the under developed and developing countries.

Wind Energy

Windmills with special features such as low cut-in velocity, low maintenance, long life, automatic regulation, full lubrication, back gearing and adjustable stroke have been developed. Low cost has been the prime governing factor and the development efforts have been directed towards a system which is cheap, simple and reliable. Secondly, the cut-in velocity has been kept low in the order of 7/8 kmph. to the maximum advantage of the available winds. (annual mean value being 12 kmph. in coastal areas). Towers made from locally availble Casurina and Eucalyptus poles have also been tried out and a strong and reliable tower design developed. Cheap steel towers have also been developed. The pros and cons of both have been studied in detail. Plunger pumps of various sizes with extra leather washers have been developed. These pumps are provided with improved valves to increase the developed pumping efficiency. The final design has been after trials spread over four years. Two models namely Model DW-200 G and Model DW-400 G with a rotor diameter of 2 meters and 4 meters respectively, have been standardised.

Further development is in progress in the field of wind power generation and other applications.

Solar Energy

Solar collectors and water heating systems (upto 70°C) are being manufactured with the guidance of Dr. C.L. Gupta of Sri Aurobindo Ashram.

Recently, 100 flat plate collectors have been quoted to a prominent concern in Madras.

Bio Gas Systems

It is also proposed to standardise biogas Systems for commercial exploitation in the near future.

Communicated by : Mr. V.C. Shah, Auto Spare Industries, Wind Machines Div., C-7, Industrial Estate, Pondicherry 605 009.

BHEL CORPORATE R & D

Hyderabad

As a part of Research and Development programme in Non-conventional Energy Sources, BHEL has the following major areas of activity under the Solar Thermal Energy Programme :

- Solar Collector Development
- Solar Heating, Cooling & Refrigeration
- Solar Water Pumps
- Solar Power Generation

Besides conducting its own R&D Programmes in the above four areas, BHEL also coordinates R & D activities in these areas being carried out at other selected organisations in the country, where projects sponsored by the Department of Science and Technology are progressing.

Solar Collector Development :

Flat-plate collectors suitable for heating water up to 60°C and upto 95°C have been developed. The collectors consist of extruded aluminium frame, roilbond aluminium absorber panels, fibre-glass pack insulation and single/double glass covers. The lower temperature range collectors are being commercially manufactured for domestic solar water heaters and for large size retrofit systems for water heating in hospitals, hotels and other buildings. The higher temperature range collectors have been used for solar power generation. These collectors are also being used for thermal energy collection for operating vapour absorption refrigeration units. The collectors have non-selective coatings of stoving black enamel paint. The efficiency of single glass collectors at 60°C is between 40 to 50 percent and in the case of double-glazed collectors the efficiency at 95°C is between 30 to 40 percent.

Over two thousand square meters of commercially manufactured flat plate collectors have already been installed in several water heating, power

generation and refrigeration demonstration/experimental projects at Hardwar, Delhi, Madras, Hissar and Bombay.

The use of selective coatings on the absorber panels will help increase the efficiency of the collectors. The development of selective coating techniques and establishment of commercial/production facility in progress.

BHEL and the Punjab Agricultural University, Ludhiana are jointly engaged in the development of Winston type of concentrator collectors for energy collection in the range of 150-200°C. These collectors are being developed for applications requiring low pressure steam and also for their utilisation in conjunction with organic vapour operated prime movers and reciprocating type of solar water pump systems. The collectors are under test and the initial test results obtained so far show promising future of large scale usage of such energy collection systems.

BHEL is also developing tracking cylindrical parabolic (trough) and paraboloid dish collectors for thermal energy collection in the temperature range of 150-550°C.

Various glazing and coating materials studies are being conducted as an input to collector development activity. Also corrosion problems are being studied for use of collectors with different types of fluids and not-treated water.

The major emphasis in this area is to develop undermentioned materials and subsytem to enable use of collectors in different environments and for different applications:

- Corrosion-resistant thin-walled steel tubing (rectangular and circular cross section).
- Clinching techniques for manufacture of tube sheet collectors to reduce bond resistance to a minimum.
- Aluminium extrusions for collector frames for ease of assembly and longer life.

- Flow patterns for roll-bonded aluminium panels for obtaining nearly isothermal surfaces.
- Aluminium foil faced insulation packs.
- Temperature resistant slip-on-gaskets, tube anchor bushes, glass sealant (rubber based adhesives silicon), etc.
- Pressed steel absorber panels and welding techniques.
- Selective coating techniques for absorber surface.

Solar Heating, Cooling and Refrigeration :

Direct use of solar energy as thermal energy has wide range of domestic and industrial applications. At the moment, BHEL's major emphasis is to develop cost-effective water heating systems of various sizes. For all such systems, techno-economic studies have been conducted for both thermosyphonic units (no pump) and forced circulation (with pump) units in order to arrive at areas of attack for cost reduction to achieve minimum cost per unit of energy collection on yearly basis and to achieve fast returns of capital invested. The Research and Product Development programme is being conducted in the following :

1. Water Heating System

Under the water heating systems, three projects are being investigated. These are:

Development of 140 to 300 litres capacity domestic solar water heaters (For large scale production). The objective of this project is to design production oriented domestic solar water heater models suitable for large-scale production. The system is based on thermosyphonic flow principle for thermal energy transfer from collector to an insulated water reservoir. Field trials on several models have shown promising results. Batch production plans are being made for manufacture of these units, initially for test marketing and for obtaining field performance and user reactions.

Medium-size forced convective water heating system : These systems consist of 10 to 50 sq. metres of collector area with a closed cycle arrangement for transfer of thermal energy from collectors to insulated water reservoir to cater for water heating requirements. The design for the system has been optimised with regard to maximum collection of solar energy with minimum possible total expense. Such a system has applications in guest houses, small-size hotels and hospitals where water without contamination can be heated with solar energy. Field trials on an experimental system operating since October, 1976 have shown encouraging results.

Two other projects, using 50 sq. metres of collector area each, are being installed at Hardwar and Hissar. The Hardwar project will be used for hot water requirements and space heating of two rooms of BHEL's guest house. The Hissar project is being installed at Indo-Australian Cattle Dairy Farm for hot water requirements. Large-scale production, initially on a limited commercial basis, is being planned for such systems.

Large-size water heating system: Under this programme, about 200-400 collectors having area of 1 sq. metre each are coupled to an existing large water heating system. The major objective is to conserve conventional energy consumption. Such a 'Retrofit' system has already been commissioned at 'Qutab Hotel' in Delhi in May, 1978. The energy delivered is expected to be about 186 million kcal per year.

Based on the techno-economic results of this project, a number of other similar projects on commercial basis are planned for execution.

2. Cooling and Refrigeraion

Under the cooling and refrigeration activity, BHEL has the following projects in hand:

1-Ton Refrigeration Unit: A 1-ton size vapour absorption system has been designed in cooperation with Indian Institute of Technology, Madras using ammonia and sodium thiocyanate refrigerant mix. The system is suitable for

operation with 95°C thermal energy input, using solar energy or waste heat. The evaporator temperatures are between -2 to -5°C wth a coefficient of performance of the order of 0.5. An experimental system has been fabricated and installed at IIT Madras and after trial runs, performance data have been obtained. Attempts are now being made to design and develop a compact unit suitable for commercialisation.

10-Ton Cold Storage Unit: On the basis of the results obtained from the 1-ton unit described earlier, it is planned to scale up the vapour absorption system to build a 10-ton unit. The unit is proposed to be coupled to an existing cold storage running with conventional energy.

Alternatively, it will be operated as an independent unit using both solar and conventional fuel as sources of energy. This project is likely to be completed by the end of 1979.

Basic studies are being conducted to establish feasibility of operating such systems in conjunction with higher temperature solar power plants and also using biogas as an additional energy source.

Solar Water Pumps:

Keeping in view the irrigational needs in rural India, BHEL is planning to develop solar water pump of 1kW capacity based on organic vapur Rankine Cycle.

BHEL is also designing a large-size organic vapour operated single stage turbine of 20kW capacity. Such units will either be used for pumping water or for electric power generation. The development work in this area is expected to be completed by the end of 1979.

Solar Power Generation:

A 10-kW experimental-cum-demonstration solar power plant using flat-plate collector was designed, fabricated and installed at IIT Madras under

the Indo-German Technical Cooperation Programme. The project which was initiated in August 1976, was successfully commissioned in January 1978. This system has basically two cycles viz; energy absorption cycle and energy conversion cycle.

The energy collection and storage system utilises flat-plate collectors to absorb thermal energy at a temperature of 90°C and hot water is stored in an insulated temperature stratified reservoir of 35,000 litres capacity.

Energy conversion cycle utilises Freon-114 as the working fluid. The system has all the necessary instrumentation, controls, and electrical storage for obtaining technical data. This data will be analysed on short and long-term basis for studying the techno-economic aspects of setting up large number of small sized units in rural areas where conventional electrical energy is not likely to be available for next 5 to 10 years. The study of data will also give sufficient information to determine the optimum size and the type of system most suitable for rural applications.

Another project on solar power generation, using tracking paraboloid dish with temperatures of the order of 300-500°C has been recently taken up by BHEL. The project is planed to be commissioned in two year's time.

Feasibility studies are also being conducted for the design and development of relatively small power plants (100-500 kW size) using Central Tower concept.

Rural Energy Package :

In order to provide basic energy needs to remote rural areas in India, Integrated Energy Systems are being developed, using solar energy and biogas. The integrated system approach is expected to be economical as compared to the individual systems to meet the basic needs of electricity, refrigeration, water pumping, and heating. Work on this project is in the initial stages at present.

National Development Coordination Programme :

BHEL has also been assigned the national level responsibility of undertaking joint development and design of production-oriented models for the projects developed elsewhere in the country. Some of the projects in hand are:

- Concentrator collectors of Winston type for temperature range of 150-200°C. A batch of these concentrator collectors is under field testing.

- Solar thermal energy collection and storage in temperature stratified reservoir is being installed at IIT Bombay for operating 1/2 - Ton size Ammonia-Water Vapour Absorption Refrigeration System.

- Fabricational techniques are being developed for production of clinched tube-sheet absorber panels for low-cost flat plate collectors for IIT Kanpur project being done in this area by IIT Delhi.

Commercial Activity:

Since the objective of all development work is to provide commercially viable products, BHEL has initiated activities to establish infrastructure for the commercial production of viable products.

Under this programme a number of small-scale manufactures are being developed on all-India basis to take up production of solar products and components initially on sub-contract basis. This is being done to ensure production of product with lower overheads and for generating interest on a much wider basis. The solar products which will be covered are:

- Flat-plate collectors
- Domestic solar water heaters of 140-200 litres capacity
- Medium and large size water and air heating systems
- Vapour absorption refrigeration system of 1 to 10-ton cooling capacity.

While the specific activities outlined will continue on a long-term basis, efforts are being made to develop new materials, systems and fabrication techniques with necessary software studies to achieve better results in terms of efficiency, economy and performance of the developed products.

Solar Energy Product Development Centre:

Plans are being prepared for the establishment of a Solar Energy Product Development Centre at BHEL Hyderabad. This centre will accelerate the conversion of R & D prototype in the solar thermal area into commercial models. The centre will have the facilities of development, design and fabrication of production-oriented prototype.

Conclusion

Within the next few years, the detailed results of the presently initiated solar energy research and development projects would have been carefully evaluated from the viewpoint of techno-economic performance. At present, however, the solar energy programmes in the country are at too early a stage to draw any firm conclusions. As in the case of all new technologies developed in the past, efficient and economically-justifiable utilisation of solar energy can also come about only by passing through an exhaustive initial stage of experimentation and evaluation.

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CENTRAL ELETRONICS LTD
Sahibabad

Genesis

Research and development work on solar photovoltaics in India before 1975 was sporadic and academic in nature. Towards the end of that year, the Government of India, through its Department of science and echnology, initiated a national programme on harnessing the solar energy. In the area of solar photovoltaics, Central Electronics Limited, a public sector undertaking producing electronic components and systems, was asked to draw a national programme on the research, engineering development and pilot plant production of solar photovoltaic cells, modules and systems. The plan envisaged a two-pronged approach. On the one hand, it was suggested that universities and national research institutions may be sponsored for goal-oriented research and development work on potentially viable photovoltaic devices and materials. Simultaneously, CEL was to initiate cost-effective manufacturing technology development for silicon solar cells, modules and systems, with an aim to first produce in a pilot plant and then commercial manufacture of these products for end use in rural India. All associated research and development, with a product-oriented goal, was also to be the responsibility of CEL. The DST accepted this plan of action and initiated sponsoring projects at CEL and various Indian universities, research institutions and other public sector industries. CEL was designated by DST as the co-ordinating and monitoring agency for the photovoltaic research projects in other institutions.

The task involved for a proper implementation and execution of the plan at CEL was not an easy one. The technology of semi-conductor devices, in particular that of the silicon solar cells, is fairly well documented. However, the cost of such cells produced is high. Therefore, cost reduction at each process step was a prime criterion. The transfer of laboratory technology, meant for the fabrication of one or two cells at a time, to the engineering development stage, where routine fabrication of hundreds of cells are involved

at a time, was the first task before CEL. The difficulties involved can be visualised from the fact that the highest reported active-area AMI conversion efficiency of silicon cell in a laboratory is around 19%, in contrast to that of a cell coming out of routine fabrication line of 15%. And of course, in a batch of large number of cells, this efficiency will necessarily vary over a range, whose control is a prime necessity. Design and fabrication of various jigs, tools and fixtures were intimately connected with the development work. Technology improvement and adaption to suit the Indian enviromental conditions were also an integral part of the development work. Photo-voltaic system development for rural and industrial applcations was an important aspect to be taken up simultaneously. Another very important, but often neglected, area of the development work is the test and evaluation of the products at all stages of fabrication and use. These were some of the tasks faced by CEL at the initiation of the project.

Indian Status

The project was sponsored in November 1975. The laboratory space was made available in May 1976, and construction work for clean rooms started immediately. Meanwhile, the procurement of essential equipments and materials were undertaken. The actual development work could start only in March 1977. By December 1977, many of the technology development work on silicon mono-crystalline solar cells and modules was standardised, and a small scale routine fabrication of cells and modules was undertaken. Various technological steps were thoroughly studied during the development work, and cost reduction, process simplification and suitable modification were effected wherever possible. Design and fabrication of various tools, jigs, and fixtures were simultaneously undertaken, their performance studied and final standardisation made. In addition, research and development work was originally initiated on polycrystalline silicon solar cells, concentrator silicon solar cells and gailum arsenide heterojunction solar cells. These developmental areas were later discontinued in order to conserve the limited resources available for the manufacturing technology development, system engineering and field testing of

systems. All these works are in a continuous stage of development to achieve better and less expensive results. The routine fabrication capacity is also continuously getting enhanced. The stress in the work at CEL is for product development, with continuous improvement in yield and reduction in cost, without sacrificing the quality and quantity. Research, perse, is given low priority, and the publication of research papers are not much encouraged.

Simultaneously with the technology development work, a well equipped test and evaluation laboratory has been set up. Starting from incoming materials, the products are tested at every stage of fabrication, and statistical data collected and analysed for future improvements. The modules of various size and capacity are throughly tested, both with simulated and actual solar insolation. Random samples of cells and modules are picked up for accelerated tests under specified temperature and humidity cycling. The test and evaluation laboratory is well equipped to collect data on solar insolation, and to test and evaluate various photovoltaics operated systems that are under development at CEL.

Routine pilot-plant production of solar photovoltaic cells, modules and systems are in progress, associated intimately with production and developmental research, primarily to reduce the cost of the system without sacrificing reliability. The capacity of manufacturing photovoltaic cells and modules has been increased by more than a factor of 10 in the last three years, and is being further augmented. However, an overall systems approach is the key to the project, and primary stress is put on the reliable and cost-effective field trials and operation of photovoltaic systems, be it a radio, television, water pump, lighting system, or any industrial application. Development of various high-efficiency, low-cost, subsystems to go with the photovoltaic energy sources has been taken up, eigher in-house or through competent outside parties.

Over the years, a large number of solar photovolatic systems, designed and manufactured by CEL with Indian expertise, has been installed in various locations in India. Some of these installed systems, as of March 1981, are listed in Table I as given in the following page.

TABLE - 1 : Solar Phototovoltaic Systems designed, manufactured and installed as of March 1981.

Water pumping systems	Community Lighting Systems	Radio/ Television	Industrial uses
1. Awania, Bhavnagar (Gujarat). 2. Tijara,, Alwar (Rajasthan). 3. Dept. of Science & Technology Campus, New Delhi. 4. Punjab Agricultural University, Ludhiana. 5. National Physical Laboratpry, New Delhi. 6. Indian Agricultural Research Institute, Delhi. 7. Central Inland Fisheries Research Institute, Madras. 8. CEL Campus. oooooooooooooooooooooooooooooooooooooooo In addition, pumping systems are in the process of being installed in Gujarat, New Delhi, West Bengal, Haryana, Mizoram, J & K, M.P., U.P., and Orissa.	i) At Tibetan SOS Children's Village at Choglamsar, Leh for the illumination of their Hospital, Kitchen and Community Hall. ii) Another system is ready for installation in Leh, Ladakh.	I) Govt. Higher Secondary Schools at Leh and Srinagar ii) Bal Bhawan Society, New Delhi and Jawahar Bal Bhawan, Mandi. iii) 25 Nos. of PV Modules to UNICEF for community Radio. iv) Community TV at CEL Campus. v) CEL modules used in a DST sponsored project for community TV at Charsarati, Kalyani, West Bengal.	i) Photovoltaic Modules for Ship Navigation at Dwarka Port, Gujarat. ii) Photovoltaic Modules for ship Navigation at Okha Port Gujarat (these have been shifted further deep in the sea at Boral Island, which is unattended). iii) Portable Battery chargers for various Remote Area Applications. In addition, CEL modules are inuse in various other industrial applications throughout the country.

A large number of such systems, particularly water pumping systems, are planned to be installed in the coming months. At least 15 more systems are ready for installation now and these will be installed shortly. In addition, a large number of solar cells and modules has been supplied to various users, such as, national laboratories, universities, commercal firms, government organisations, etc., for their use. A comprehensive consultancy service is available at CEL for users' education and assistance. CEL is presently negotiating and consulting with various government concerns, such as the Oil and Natural Gas Commission, the Post and Telegraph Department, the Railways, the Defence, the Space Research Organisation, etc., for meetng their requirements, Nonetheless, the major objective of the project in CEL is to supply reliable and cost-effective solar photovoltaic systems, particularly water pumping systems, for use in rural India.

Future Programme

The major thrust of any terrestrial solar photovoltaic research and development work is finally to produce techno-economically viable photovoltaic systems for public to use. Industrial applications of solar photovoltaic energy sources are presently beyond doubt. Nonetheless, in India the true public use will be in more than half a million villages. The DST/CEL plan of action takes full cognisance of this fact. The technical viability can only be judged by actual field trials of these systems. No amount of laboratory trials can definitely prove the technical viability. The economic viability can be achieved by concerted and goal-oriented research and development activity, and mass-scale production of these cells, modules and systems. Finally, one must not forget that major raw materials necessary for this mass production must necessarily be made locally available, and dependence on other countries must be minimised. It is of necessity that large-scale government support will be essential, because no commercial firm will invest in a product, for which there is no market at the present moment, because it is not economically viable.

Based on these broad guidelines, a National Solar Photovoltaic Energy Demonstration (NASPED) plan has been drawn up and is being implemented. The programme includes the setting up of a pilot-plant facility at CEL to produce more than one megawatt (peak) of solar cells, modules and systems per year by the end of the present five year plan period. The associated research and development, particularly on materials, have also been taken into consideration. Large-scale field trial and evaluation of the photovoltaic systems are envisaged in this plan. It is anticipated that at the end of the project period, the experience gained will generate enough confidence and expertise to venture mass-scale commercial production in the photovoltaic system area. Nonetheless, the industrial use of solar photovoltaic energy sources is a reality today and CEL has taken that fact into its planning also. Such industrial applications will be taken up by CEL beginning 1981-82, on a fairly large scale.

Communicated by : Dr. T.K. Bhattacharya, Solar Cell Project Manager, Central Electronics Ltd., Sahibabad (U.P) 201 010.

ELECTRONICS CORPORATION OF INDIA LTD.

Hyderabad

ECIL was being actively considered during the year 1971 as the most suitable place for productionising space quality silicon solar cells required for the Indian Space Research Programme. Soon after, a small group was formed, to be the nucleus for productionising space quality silicon solar cells. By 1972 ECIL had a reasonably good base for the manufacture of discrete semiconductor devices. In the same year, ECIL successfully completed pilot plant production of Czochralski silicon single crystals, which were subsequently used in ECIL's solar cell development work. In recognition of its pioneering work and excellence in research and development of silicon crystals, ECIL received the Electronic Component Industries Association (ELCINA) award for 1975. Also, by 1975 ECIL was able to achieve energy conversion efficiencies of 10-11% for its silicon solar cells, manufactured in small batches, using Ti-Pd-Ag evaporated contacts. Due to inadequate vacuum coating facilities, the production batches were not consistent, and also due to various other limitations large-scale production was not taken up.

Cheap grid contacts on the active surface of silicon solar cells are very essential for the success of any photovoltaic energy conversion systems. Ti-Pd-Ag evaporated contacts are used for space quality solar cells in the past for their adherence, low series resistance, long life, soliderability, good mechanical strength etc., but they would be prohibitively expensive for terrestrial solar cell power systems. Hence ECIL undertook a Grant-in-Aid project from the Department of Science and Technology/Central Electronics Ltd. for the development of suitable grid contacts for low cost normal concentration and medium concentration silicon solar cells. Under this scheme, ECIL has developed a process using electroless plating of nickel and gold and electroplating of copper for the metallisation of silicon solar cells in which the critical step of selective etching of the metal layers is eliminated. Some silicon solar cells fabricated using this process were handed over to CEL in February 1977. Though this type of metallisation has good mechanical strength and easily

solderable, its long range performance under humid environment has not been evaluated. Silver paste screen printing technique also has been tried with reasonable sucess.

In view of the already existing strong base in silicon crystal growing and silicon solar cell manufacturing, ECIL had submitted a project report to National Science Foundation of U.S.A. under the Indo-U.S. Joint Commission through DST/CEL for studying the role of impurities in silicon solar cells, with the purpose of utlimately evolving the specifications of solar grade silicon. The proposal envisaged adding individually or together known quantities of impurities such as Ti, Va, Ni, Cr, Cu, Fe, Zr etc., at the time of crystal growth and study their effects on silicon solar cells made out of these crystals. The project never materialized on the plea that work was being done in some of the U.S. laboratories on similar lines.

ECIL has a separate division with production facilities for the manufacture of large area (upto 10 metres in diameter) antenna dishes which can serve as reflectors and concentrators for large-scale solar energy conversion applications. ECIL has the capability in silicon single crystal growth, manufacture of silicon solar cells and large area reflectors/concentrators besides excellent environmental and other test facilities.

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HINDUSTAN BROWN BOVERI LTD.

Baroda

With the establishment of a Centre for Research and Development, a small group has been working since 1977, to explore the areas of solar energy and develop technologies which are of immediate use and those which look promising in the long term. Theoretical studies are made, backed up by actual working models to test the concept and gain field experience.

Completed Research Projects

Solar Water Pump Mark I : A 10,000 litres per day capacity solar pump with 10 m head installed during January 1978 was successfully tested and technical problems overcome. It is a fully automatic plant where the energy required for automation is powered by a lead-acid battery which in turn is energised by a small photovoltaic panel. This project was completed in August 1980.

Solar Water Heater : Both domestic and industrial water heaters have been developed in the domestic sizes (200 - 500 litres capacity), offering in three types with builtin storage tank, thermosiphon and two phase water heater (patent pending). The builtin storage type is useful for low capacity and ideal for a small family (4-5 members). Higher capacity upto 400-500 litres are met by thermosiphon heaters, and where scaling and night freezing temperatures are encountered two phase water heater is recommended. A builtin storage type (150l), a thermosiphon and a two phase water heater (both of 400 litres) erected in 1978 have been working satisfactorily to date. The industrial water heaters was designed for long life (10-15 years) with very low maintenance and optimum extraction efficiency (employing a differential temperature controller) that can be adjusted to suit different customer's requirement. In fact, the industrial water heater can be designed to retrofit into existing system of varying specifications. An industrial water heating unit of 1600 litres was commissioned for a canteen and is working satisfactorily for the past one year. It caters to utensils cleaning and preheating for tea and rice preparation.

Collector Development : Two designs of flat plate collector with two phase working fluid has been completed and tested (patents pending). The unit is modular in construction and the components used are suitable for site assembly to reduce installation cost. The units are designed for 10-15 years of life and can withstand certain types of hard water where indirect system is not preferred. In case DM water is used, longer life can be expected.

Ongoing Research Projects

1. Solar Air Heaters : Three types of collectors have been designed for testing and the most efficient one has high efficiency and low pressure drop. The commercial model is undergoing testing using computer optimisation. The attractive features are good ducting design for almost uniform flow distribution and flexibility in site assembly to reduce installation cost. This unit can be used for any drying application, for example, in chemical, pharmaceutical, fisheries, agriculture etc.

2. Selective Coating : Good optical properties and stability at 150-250°C even in the presence of small amount of moisture are desired. Initial test samples proved promising stability, while accelerated ageing tests are going on.

Demonstration Project

A Solar Desalination unit is to be installed for field testing shortly.

Laboratory and Test Facilities

Instruments :

a) Radiation Measurements - Global and Direct. Continuous recording with integration facilities.
b) Wind recorder.
c) Ambient Temperature & Humidity Recorder.
d) Temperature Recorders & Indicator.
e) Flow meters for liquid and gases.
f) Reflectivity, absorptivity and emissivity meters.

Test Rigs :

a) Thermal performance of flat plate collector and concentrator.
b) Two phase collector test set up.
c) Air collector test unit.

Future Programmes

High temperature collector development (200-400 °C).

Publications

1. R.S. Soin, S. Raghuraman, K. Sudhakar and D.P. Rao, "Two Phase Water Heater", NSEC, Bombay, Dec. 1979.

2. R.S. Soin, "Viability of Solar Based Industrial Process Heating", AIEI Energy Conference, New Delhi, Feb. 9-11-1981.

Communicated by : Mr. R.S. Soin, Research Engineer, Hindustan Brown Boveri Ltd., Post Box 284, Baroda 390 001.

JYOTI LTD.

Baroda

1. Introduction

Jyoti initiated its research and development efforts in the area of renewable sources of energy more than five years ago. The level of efforts, since then, has consistently increased culminating in the establishment of a separate Energy Division in May 1978. The Division now offers a number of products for effective to an all-encompassing effort in the field of solar energy. The Division is also actively working in the areas of wind energy and bio-conversion and offers its expertise for effective energy management both with conventional as well as renewable sources of energy.

2. Projects Completed

A number of research and development projects have been completed during the last few years resulting in a range of solar and wind energy conversion systems. Some of these projects and the resultant products are described below :

2.1 Solar Hot Water Systems :

Jyoti's solar product range begins with hot water systems with a variety of options for applications particularly in industrial and commercial establishments. The systems are modular in nature with Jyoti flat plate collectors being the basic building block. A standard Jyoti flat plate collector (1 m x 2 m in size) will, on an average, deliver approximately 125 litres daily at 60 ^{o}C or 70 litres daily at 80-85 ^{o}C. A number of system options are offered with a varying degree of sophistication. The range begins with just the flat plate collectors with no storage and goes all the way upto a solar system having an integrated conventional back-up automatic control to ensure hot water availability.

For large commercial and industrial systems, proper integration of solar systems with the existing conventional systems or with the building architecture is also offered.

While the standard flat plate collectors described above are based on black paint for the absorber and glass as the glazing material, the second generation collectors already being offered uses black nickel selective coating as the absorber and U.V. stabilized acrylic as glazing.

2.2 Solar Hot Air/Drying Systems :

The Energy Division currently offers three different solar dryer configurations capable of meeting a wide range of applications. The configurations are:

- Jyoti integral solar collector-cum-dryer (Jyoti HAS-I).
- Jyoti convective collectors-cum-green house dryer (Jyoti HAS-II).
- Jyoti modular solar hot air system (Jyoti HAS-III).

Integral solar collector-cum-dryer (HAS-I)

In this option, the drying chamber roof and front are converted into solar collectors. The air heated through this integral collector is drawn into the chamber using exhaust fans (or suction fans) depending on the size of the chamber. With the use of integral collectors, the temperatures inside the chamber are maintained 10 to 15 ^{o}C above the ambient temperatures. This alongwith the forced flow through the product being dried, results in acceleration factors of 2 to 3. The chamber is designed such that the project is not exposed to direct sunlight. The concept is largely modular in nature and the dryer could be designed for the given product load.

Convective collectors-cum-greenhouse dryer (HAS-II)

This system consists of a glass greenhouse connected to a number of flat plate collectors for air heating. The air flow is largely due to natural convection and is aided by a chimney provided with the greenhouse for the purpose. Use of induced draft fans result in increased efficiency for such a dryer. The collectors and the greenhouse result in air temperature in the chamber that are 20 to 30 ^{o}C above the ambient and the drying rates can be 2-4 times those for open sun drying. The product, in this option, is exposed to direct sunlight through the glass house.

Modular solar hot air system (HAS-III)

Available in 1 m x 10 m module standard units, are capable of delivering hot air upto 80 ^{o}C during sunshine hours. One square meter of collector area can deliver approximately 160 kg of hot air at 75 ^{o}C on a bright day. This works out to a total annual heat delivery of as much as 48 x 10^{4} kcal, equivalent to 560 kWh per square meter of collector area. Special system can be built to suit specific requirements at even higher temperature as high as 100 ^{o}C. The system can operate during sunshine hours only; in other words no storage facility is provided.

For application requiring lower temperature (say 50 ^{o}C to 60 ^{o}C), the system capacity is even higher with one square meter of collector area delivering as much as 400 kg of hot air on a bright day.

2.3 Solar Desalination Systems :

For distilled water requirements covering the range of a few litres to a few thousand litres daily, they offer solar desalination systems integrally moulded in fibre reinforced plastic. For small requirements, the portable still comes in very handy with its 1 sq.m. area delivering approximately 3 litres of distilled water daily.

The larger requirements are met by interconnecting a number of portable stills that have been specifically designed to facilitate such inter-connection. The integral mould using fibre-glass reinforced plastic (FRP) has resulted in a unique device which overcomes all the problems identified with the conventional solar stills. This concept also avoids extensive site work that is necessary for brick masonary construction and at the same time ensures effective collector control.

2.4 Wind Energy Conversion Systems:

The 40 watt system consists of a 2 bladed wooden rotor, which drives a d.c. generator directly, the d.c. output being used to charge a lead acid battery. The system also includes overspeed control, manual brake, over charging and over draining protection for the battery.

The 350 watt system consists 3 bladed rotors and are coupled to the electrical system which involves variable frequency a.c. generator with induction motor-pumpset, through a step-up gear box. Rectified d.c. output could also be obtained and stored in batteries as an option. The systems have overs-speed control and manual brakes.

The project on development of Wind Energy Conversion Systems has resulted in two wind energy conversion systems so far.

2.5 Solar Cookers

There are two basic sizes offered by Joyti. The "family size" cooker is designed to be adequate for a small family consisting of 5-6 people. In this option, the mirror is directly attached to the box and adjustments are made by slight movements of the whole cooker assembly. The cooker is supplied with four round vessels and, therefore, as many as four different dishes could be done at a time.

The second option - industrial cooker - is largely meant for small canteen use. In this case, the booster mirror is provided on a separate stand and

all adjustments could be made with the mirror itself having the large cooker box stationary. Instead of round cooker vessels, shallow flat trays are provided for more effective utilisation of the cooking space.

3. On-going projects

3.1 Solar Pond:

Solar pond is an economic low grade thermal energy collection system. Its applications are mainly in the sphere where hot water is required. It can also be coupled with vapour absorption refrigeration system as well as with organic expanders for small scale power generation.

3.2 Solar Powered Cold Storage

Solar cold storage systems are based on acqua ammonia absorption refrigeration system. Minimum evaporator temperatures can be well below 0°C. Overnight storage facility is provided in the form of product storage.

3.3 Solar Thermal Power Generation Systems:

Solar thermal power generation systems are based on concentrating collectors-cum-steam. It is meant mainly for decentralized small scale power/electricity needs of remote rural areas.

3.4 Steam Engine Systems:

The steam engines to be offered by Joyti Energy Division begins from a single cylinder engine capable of delivering a few kilowatts to multi-cylinder engines delivering 20? kW or so. The engines have been developed with a built-in flexibility to cover a very wide spectrum of application and system options. Some salient features of the steam engines are given in the following page:

- medium steam temperatures and pressures to ensure that all available energy sources could be effectively used.
- steam thrifty, that is, they have a very low specific steam consumption.
- capable of a wide turn-down while still largely retaining the low specific steam consumption, thereby resulting in very efficient part-load operation.
- while the design steam conditions are around 10 kg/cm^2 pressure with about 20°C superheat, the engines can continue to operate even at very low steam pressure of 3 kg/cm^2.
- because of the relatively high speed operation, the engines are very compact.
- capable of running in both condensing mode as well as the non-condensing mode.
- rugged and reliable

The details of various models of the joyti steam engines ranges are given in table I.

While the steam engine models SC-1 to SC-6 are expected to be available by the end of 1981, the models SC-4 to SC-8, will be ready before end of 1982.

TABLE - I : Specification for Jyoti Steam Engines

Engine Model	SC 1	SC 2	SC 4	SC 6	LC 4	LC 6	LC 8
Number of Cylinders	1	2	4	6	4	6	8
Bore X Stroke (mm)	110 x 116	110 x 116	110 x 116	110 x 116	175 x 220	175 x 220	175 x 220
Speed (rpm)	1500	1500	1500	1500	1000	1000	1000
Gross power from the engine (at 10 kg/cm^2 and 2000°C as inlet and 0.2 kg/cm^2 as exhaust steam conditions in kw)	6.0	12.0	24.0	36.0	76.0	114.0	152.0
Total auxilliary power (kw)	0.97	1.94	3.88	5.80	11.30	16.45	22.00
- Vacuum pump	0.25	0.50	1.00	1.50	2.50	3.50	4.50
- Cooling water circulation pump (kw)	0.05	0.10	0.20	0.30	0.50	0.75	1.00
- Boiler feed pump	0.07	0.14	0.28	0.40	0.80	1.20	1.50
Specific steam consumption at design conditions. (kg/kwh gross)	15.0	15.0	15.0	15.0	14.0	14.0	14.0
Specific steam consumption at design conditions.	18.0	18.0	18.0	18.0	15.5	15.5	15.5
Net brake thermal efficiency (%)	7.4	7.4	7.4	7.4	8.6	8.6	8.6

3.5 Solar Low Pressure Steam Generation Systems:

The development work in this area is expected to be completed soon with the low pressure steam collectors and systems being commercially available by 1981. The collectors are based on a novel free forming technique for the reflector, centre of gravity tracking, very light structure and sandwich mirrors. The temperature capability will be atleast 140°C with a very high optical efficiency.

3.6 Wind Energy Conversion Systems having a capacity of 1 to 10 kW are currently under development.

4. Laboratory and Test Facilities:

Energy Division has been established with the object of development of technologies for effective utilisation of various renewable sources of energy, particularly solar energy, wind energy and bioconversion. The Division is set up in a 12,000 sq.m. up-to-date, well equipped complex at Tandalja, Baroda and the available laboratory facilities include the following:

1) Engine testing laboratory for Rankine cycle based prime movers of upto 10 kw capacity consisting of a boiler and a dynamometer set up.

2) Flat plate collector test facility for individual and comparative testing of solar collectors.

3) Accelerated enviromental test laboratory with special ultra-violet lamps - an acceleration factor of 10.

4) Component test laboratory for solar and wind energy conversion systems.

5) Windmill testing facility.

6) Experimental solar pond.

7) Instrumentation laboratory.

8) Data logger with a mini-computer for continuous monitoring and performance analysis of solar and wind systems.

The Division also has a complete meteorological laboratory with extensive facilities for measurements of solar insolation data, wind velocities, etc. This includes pyranometers and pyroheliometers with integrating, anemometers, hand held anemometers, and turbine meters for instantaneous wind velocity measurements, wind vane, rain gauge, humidity meters. Facilities also exist for measurements of important optical properties like emissivity, reflectivity as well as transmissivity.

Over and above this, the Division has open platforms for testing the solar components/systems as well as for demonstrating their performance.

Experties is also available for construction services in the area of energy management for industries, backed by necessary laboratory facilities.

5. Future programmes envisaged

The Division expects to shortly undertake development work in the following areas:

a) Biomass gasifiers and dual-fuel engines.

b) Fractional kW solar thermal power generation systems

c) Industrial biogas plants based on agricultural wastes.

d) Rural energy centres based on various renewable sources of energy.

6. List of latest publications

1. Renewable energy sources for India by Dr. B.C. Jain, Physics News, Special Issue on Alternate Energy Vol. 11 No. 4, Dec. 1980 pp. 128 - 130.

2. Solar energy - applications in textile sector by Dr. B.C. Jain presented at the seminar on Productivity in Textile Sector organised by National Productivity Council at Ahmedabad in December 1980.

3. Development in the area of non-conventional sources of energy at Jyoti Ltd., by Dr. B.C. Jain preseted at the Energy Conference organised by the Association of Indian Engineering Industry in February 1981.

4. Development role of renewable sources of energy and efforts at Jyoti's Energy Division by Dr. B.C. Jain published in Industrial Baroda - A Review brought out by Baroda Productivity Council.

5. Studies on solar hot air collectors by V.V. Satyamurty, V. Ramakrishnan, Dr. B.C. Jain — Proceedings of National Solar Energy Convention, 79, IIT, Bombay December 1979.

6. Thermal performance of cylindrical parabolic concentrators, R.K. Gupta, R.C. Patel, Barve, Dr. B.C. Jain - Proceedings of National Solar Energy Convention '79, IIT, Bombay December 1979.

7. Experience with a large size solar hot water system by U.K. Pandya, A.P. Gulati, N.R. Yardi, Dr. B.C. Jain, Proceedings of National Solar Energy Convention '79, IIT, Bombay December 1979.

8. Development of 2 kW solar powered steam engine system - by A.M. Deshpande, R.K. Gupta, K.M. Barve, B.C. Jain - Proceedings of National Solar Energy Convention, '79, IIT, Bombay December 1979.

9. A low lift solar water pump by M.P. Sharma, Gajendra Singh (Asian Institute of Technology, Bangkok, Thailand) - Solar Energy Vol. 25 No. 3, '80.

10. An automatic valve mechanism for a diaphragm pump by M.P. Sharma, Gajendra Singh (Asian Institute of Technology, Bangkok, Thailand) presented at the Seminar on Plant Instrumentation and Control, December '80 organised by the Institute of Engineers (India), Vadodara Centre.

Communicated by: Dr. B.C. Jain, Manager Energy Division, Jyoti Ltd, Tandalja, Baroda 391 410.

PATEL GAS CRAFTERS (PVT) LTD.

Bombay

The Company is one of the pioneers in the design and manufacture of biogas plants and appliances, approved by Khadi and Village Industries Commission, Bombay. Current research topics include seeding feed slurry with ripe slurry, feasibility of plastic gas holders, collapsible gas containers and cost reduction by optimising and redesigning gobar gas digesters.

Seeding Feed Slurry

It is known that the acid formers in an anaerobic digester are more prolific - they are able to survive, thrive and multiply in varying temperatures and even, when partially exposed to air. The methane formers are delicate, strict anaerobes and slow to multiply. They are affected by sudden changes in temperature. Even a brief exposure to air is detrimental to them. It is known that higher population of methanogens, help produce more gas even at comparatively low temperatures. The digestion cycle can be reduced to an extent if methanogen population is kept up.

A venturi type of mixer is designed. In small scale trials with coloured water it has worked well. A patent application has been filed, pending field trials. One field trial was undertaken in a village community plant. It could not succeed probably due to two reasons : (1) The silt with cattle dung was not seperated, while filling and working the plant - the working was very irregular. The inference is that this part of the digester must have silted up. (2) A small bend was introduced, and the orifice was reduced to 3" diameter from a four inch pipe, which might create an obstacle. Whatever the reason, the feed pipe gets choked. Since the plant is lying idle for more than a year for reasons connected with management, no further information could be obtained.

Another trial on a 140 cubic meter gas per day size plant has been undertaken. The plant has been filled and is slowly brought to capacity run. A major obstacle in evaluating results is completing of a control trial.

Alternate Materials for Gas Holders

There are two three complaints about mild steel gas holder now in common use in biogas plants in India. That the mild steel is very costly - its fabrication is also costly. Cost is further augmented by the fact that these m.s. gas holders have to be fabricated where electric power is available and then transported to the site of biogas plant. The cost factor has been further complicated by shortages, resulting in unofficial soaring in price of mild steel. That the m.s. gas holders corrode quickly. A few cases have reported 5 years life. A larger number have reported 8 years before repairs and most of them have reported 10 years life. In most cases neglect in regular painting has been the main reason. Investigation has shown that the mild steel available in the country before 1960 was corrosion resistant. Some gas holders in use from 1951 are still in use. A piece from such old gas holder was examined. It was revealed that there was a trace of copper in that steel. Such steel is available even at present at an added price of Rs.1,000/- per tonne.

Rigid PVC was tried. It had several drawbacks. First of all the right gauge of sheet was far too costly. Thin gauge quickly cracked due to creep. Another trouble was deterioration due to solar radiation.

Preliminary trials for the fabrication of a cylindrical rigid gas holder are in progress at Valvod, a village. Low density processed (recycled) polythene pipe is being coiled and fused. It will require a minor stiffener.

Gas holder made from G.I. sheet was successfully tried at the KVIC R&D Centre at Kora Kendra, Borivili, Bombay. Now a field trial is undertaken at Rohit Colony, Pardi Taluka, Dist, Valsad in a 6 cub. meter gas/day plant. It cost Rs.1,000/- less than the m.s. gas holder. 20 gauge G.I. Sheet is used. Sand is used on top to bring the pressure to 9 cm water column.

Optimised Digester Design

Following the work at ASTRA, the Company has optimised the digester design of the Rohit Colony plant. A saving of 30% in materials of construction

is achieved, without reducing the volumetric content. The gas holder in this particular case is highly optimised. The saving in digester construction will also be Rs.1,000/-.

Collapsible Gas Container

It is visualized to have the following advantages in adopting collapsible gas containers (cc) :

1.25 m^3 cc in community plants: (a) Can result in sizable saving in outlay by completely avoiding gas pipe laying, (b) makes possible to meter gas without the use of gas meters - which are out of reach in any case. (Distribution of gas limited to cooking time twice a day has its own problems), (c) it is far more easier for the consumer to pay a small amount for a cc full of gas, than to pay every month, (d) cash sale is also assured - gas can also be easily bartered for cattle dung or other organic waste, (e) a consumer need not be on gas main, he could be anywhere in the village.

In small size plants, the costly m.s. gas holder can be replaced by cc placed indoors near the kitchen. Not only large saving in gas holder and piping are expected but saving is also expected in digester construction. Loss of heat from digesters through gas holders, which is considerable can be prevented.

A cubical design is planned. Two materials are to be tried: PVC sheet supported by knitted cloth and Latex coating of readymade knitted bags. Initial results are expected after six months.

Communicated by : Shri Jashbhai J. Patel, Chairman, Patel Gas Crafters Pvt. Ltd., 20 Shree Sai Bazar, Mahatma Gandhiji Road, Opp. Railway Station, Santacruz (W), Bombay 400 054.

OTHER INDUSTRIES

Advani - Oerlikon Ltd. Pune.

Advani-Oerlikon Limited, with considerable experience in the field of welding and electronics started development in non-conventional energy sources during early 1978. An effective programme has been chalked for the development of solar energy. It encourages both in-house R&D work and commercialisation of the products developed in the country.

The major development of R&D is Ador Solar Water Heating Systems. The solar collector panel overall measurements are 1900 x 900 x 160 mm with double glass configuration. The absorber is made of two G.I. sheets with built-in channels properly welded. The channels (24 Nos.) are designed to achieve high collector heat removable factor. All panel containers will be fabricated with 20 gauge metal and painted. The bottom of the absorber is insulated with 80 mm thick fibre glass insulation. The storage tanks for thermo-syphon systems are available in 125,225 and 325 lit. capacities. The forced circulation systems for large installations also can be handed efficiently. The electronic control units for heating systems have also been developed. The development work on selective coating for above solar panels is in progress with collaboration of a leading research institute.

Other important projects at different stages of development are Solar Air Heating Systems, Concentrators, Pumping Systems and Airconditioning Systems.

Aero Agencies (Pvt) Ltd., Bombay

A master die for plastic fresnel lens was designed, fabricated and exhibited at the National Solar Energy Convention, held at Annamallai University, Annamallainagar during 1980. The die can be made by simple machining technique.

A solar cooker has been designed and fabricated using fresnel lens. Trials are underway for determining the optimum parameters. Funding is

awaited for a proposal to design a system that will be suitable for industrial process heat.

Fabrication of fresnel lens of around 1,200 mm aperture will be taken up shortly. Also, a water pumping windmill is planned for Karjat Taluka in the state of Maharashtra.

B.S. and Services (Pvt) Ltd., Bombay

The Company began work on solar energy utilisation during 1977. Solar water heating systems for domestic, commercial and industrial applications have been developed. These have thermostatic flow control systems. Current efforts are to make higher efficiency collector panels with selective coatings. Future plans include development of solar refrigeration and air-conditioning systems.

Kelvinator of India Ltd., Faridabad

During the last 4 years, the Company has been working on solar air heaters, solar water heaters and solar cookers.

Work on solar water heater commenced during July 1977. Pending patent application, the Company has installed solar water heaters with police department and with private organisations. These systems are working satisfactorily for the last more than three years. It is now proposed to install about 200 sq.mtr. solar heating collectors for preheating of the company's paint shop.

Work on solar air heater commenced during June 1979. The design has been standardised after making many prototypes and testing them. Air temperature in the range of 70-80 ^{o}C with air flow at the rate of 30 cfm with 1 sq. mtr. heating area has been achieved. Total cost of the project was about Rs.5 lakhs. The heaters would be of use to tea gardens and the company proposes to set up pilot project shortly.

Work on solar cooker commenced during June 1980. Prototype models have been made in the laboratory. Commercial production of solar cookers is expected shortly.

Voltas Ltd., Bombay

Voltas Ltd., initiated research and development of windmills in May 1979. Two prototypes have undergone rigorous field testing even in high wind velocity conditions of around 100 kmph. Structure and other components have withstood these streneous conditions. Based on this, an initial batch of ten windmills is under production. Current projects include further research work on the pumps used for these windmills with the objective of increasing the capability of the windmill to operate in a broader range of wind velocity conditions, thereby increasing its effectiveness. Also, the development of pumps and other windmill components for working under higher heads.

Laboratory and test facilities include various test rigs and circuits for testing the pumps, under various conditions. Full fledged R&D Centre of the Company enables manufacture of prototypes and preparation of drawings without difficulty.

Future work in the area of renewable sources of energy include : Use of windmills for other agricultural applications and power generation; more effective use of animal energy; design and application of better biogas plants and irrigation pumps running on biogas and development of inverted windmill water turbine.

APPROPRIATE TECHNOLOGY DEVELOPMENT ASSOCIATION

Lucknow

Indoor Solar Cooker

ATDA has felt that the solar cookers developed so far by various organisations are outdoor type and have many limitations. This project envisaged the development of indoor solar cooker which should be able to cook the morning and evening meals of a moderate family and should be independent of the brightness of the sun within a reasonable limit. Thermic Oil is to be heated by solar energy upto the temperature of 300 to 400°C. The oil is then circulated through a hot plate having fins to draw heat from the heated oil. Another hot plate is provided at the top of the oven. The heated oil from the storage, kept on the top of the roof, is circulated for indoor cooking by a closed loop oil circulater. This system converts manually supplied potential energy to the flow energy for the circulation. The mathematical equation for the model has been solved successfully. The project will cost about Rs.1 lakh for the development work.

Micro Hydel Project

ATDA has taken up a project of developing low cost micro hydel systems for use in isolated villages of Uttar Pradesh Hills, which are away from the grid mains. Although there are other sites where micro hydel stations can be installed, there is hesitation in putting them up because of comparatively higher initial capital cost and also because the load factor on these stations is generally very low.

ATDA is working with the idea to appreciably cut down the capital cost of micro-hydel station and also reduce considerably the operating and maintenance expenditure. Simultaneously efforts are also being made to create enough end-uses to boost up the load factor to 50-60% against the load factor (of 15-20%) available at the present micro hydel stations in the area.

A survey of the existing micro hydel stations was undertaken and the site for the first project has been identified at the village Kuthnaur which is at a distance of 15 Km from Barkot on Barkot - Yamnotri Road in the Uttar Kashi District. A size of 25 KW has been standardised and the range of head will be 10 to 25 meters. Selection of suitable low cost hardware has been identified and actual work at the site will be started as soon as the licence for generating and distributing electricity is granted by the Government of Uttar Pradesh. It is expected to cut down the initial capital cost to at least 40% and the operation and maintenance cost by at least 25% of the present day expenditure in such stations. The cost of this project is approximately estimated at Rs.5 lakhs.

Bullock Lift Pump

The team of ATDA and PRAD has developed two kinds of pumps, one based on piston principle and other based on diaphragm principle. Field test results of both the devices have been very encouraging and are summarised as below:

Lift capacity per hour is 4500 to 5500 gallons from a depth of 6-7 metres, by a pair of bullocks.

These pumps are being subjected to intensive demonstration test before being declared fit for extension.

Communicated by : Mr. M.K. Garg, Director (Projects), Appropriate Technology Development Association, Projects Division, Post Box 311, Gandhi Bhawan, Lucknow 226 001.

CENTRE OF SCIENCE FOR VILLAGES

Wardha

The centre started working in the renewable energy sector, ever since it was founded in the year 1976. The initial interest has been on exploring and identifying areas in which different alternate energy sources can be used in rural areas. As a part of the research work, various types of solar water heaters and solar cookers are being tested. Testing is being accomplished on inexpensive shallow horizontal water heaters. An experiment on Algo-culture was conducted. Further experiments are in progress. The Centre has undertaken projects for the introduction of renewable energy sources in the village areas. As a result of this investigation work, a project on biogas will be implemented during the course of three years.

Biogas Project : Areas of Work

The main focus of work is on designing, fabrication and field testing of prototype biogas plants where basic research and development work done at various laboratories would be utilised and tried out so as to arrive at systems which are feasible at the village level. The area of work is briefly presented below :

1. Equipment design engineering and improvement of digesters :
(a) Prototype work on plants based on Chinese designs to test improvements (approx. 3 prototypes) (b) Design and fabrication of small volume modular-unit digesters (approx. 6 prototypes) (c) Construction design of digesters using finite elements, composite/combination materials to arrive at very low cost, locally fabricable designs. (In collaboration with the Construction Technology Programme).

2. Digestion process engineering studies : (a) 2-stage digester design based pilot-plant studies on separation of acidic and methanogenic phases. (In Collaboration with IIT (Delhi) (b) Environmental variation studies on two-existing designs (KVIC/Chinese) and methods for field control.

3. Feed-stock processing and plant design studies : (a) Trial runs on pilot-plants of existing designs of various feed-stock preparations (b) Plant equipment designs (c) Community latrine designs and design of collection containers.

4. Slurry processing and plant design studies : (a) Composting with other wastes, fortification to get desired "NPK", (b) Use of supernatent fluid for algae cultivation, and study algae-fish chains, (c) Plant equipment design, (d) Design of distribution containers.

5. Application of Bio-gas for use in rural industries selection of bio-gas system: (a) Energy balance analysis and studies related to straw pulp digesters and trial of energy system solutions (b) Investigation on the usage of CO_2 and study on repercussion on bio-gas systems design. (c) Systematic analysis of energy requirements in rural industries and specifications of digester designs and biogas systems.

Under the above project a system for biogas utilisation will be attempted. This includes (1) Feedstock raw materials collection from "M" and "S" villages; processed slurry distribution for farmers through sales "points" in "M" and "S" villages, processed feed-stock distribution to rural industry users; and collection of raw slurry; and cleaning and maintenance of biogas units (2) Feedstock with construction agency at "M" and "S" villages for fabrication, repair and maintenance functions, and production of accessories.

In the above framework, the Bazar village will be covered by the collection-distribution network. The feasibility of realising the system outlined would rest on the various elements constituting it, and which needs investigation.

Conferences and Workshop

During December 1977, a seminar on the use of solar energy in rural areas was held in Collaboration with the Appropriate Technology Development Association Lucknow. In January 1978 an International Workshop on techniques

for the rural third world was organised at Sewagram. One of the main areas of discussion was energy. Subsequently in September 1978, a workshop on Gaon Ke Karigar Aur Scientists was held in Sewagram in Collaboration with the CSIR. As a follow-up to this workshop, a scientists meeting was held in December 1978, which was attended by Senior Scientists and Directors from various Laboratories.

Future Programmes/Activities

The Centre is currently operating five projects. In addition to the work on biogas systems and solar energy utilisation devices, other areas of work include animal-powered devices for rural industries, man-powered devices for rural industries, wind power systems. The National Aeronautical Laboratory is undertaking a windmill technology project in collaboration with this Centre.

The centre proposes to set up a documentation and information dissemination unit and is currently publishing a monthly bulletin "Science for Villages".

Communicated by : M.A. Sathianathan, Coordianator, Energy and Environment, Centre of Science for Villages, Wardha 442 001.

GUJARAT ENERGY DEVELOPMENT AGENCY

Baroda

Gujarat Energy Development Agency (GEDA) is a registered society set up by the Government of Gujarat in the year 1979 to promote research and development in the field of energy, especially the renewable sources of energy. As far as the power situation goes, the state is finding itself increasingly dependent on thermal power plants. The present low proportion of contribution from nuclear power will dwindle further and no additional contribution can be expected from this source until the late eighties, given the relatively long time periods associated with nuclear power plants. In the area of non-commercial sources of energy, Gujarat is particularly vulnerable over the firewood situation given that only about 8% of its land is forest land.

Objectives :

1. To formulate and implement demonstration projects aimed at providing total energy requirements of remote villages and/or other selective utilisation centres by harnessing solar, bio-gas, wind energy and other renewable sources with the object to evolve long term plans based on the same.

2. To identify and formulate proposals for setting up demonstration of energy plantation projects within the state.

3. To sponsor, co-ordinate or promote research programmes or projects for development of proto-types, pilot plant investigations, etc., in the area of new sources of energy.

4. To advise the State Government, Panchayats, Municipalities, Municipal Corporations and other local bodies and semi-government agencies and other development agencies in the state and elsewhere on all such matters pertaining to alternate energy resources, as may be referred to it from time to time.

5. To undertake on its own or in collaboration or other arrangements with national or international agencies programmes of research, development, application and extension as related to various energy resources.

6. To establish, at an appropriate stage, its own facilities for Research and Development in the Energy field bearing in mind the available facilities in the country for similar work and the broad national strategy in this regard.

7. To undertake or sponsor studies of environmental effects of all energy related processes.

8. To sponsor or undertake techno-economic or socio-economic studies or analyses with respect to new sources of energy.

9. To provide technical, financial or other assistance for the formulation of programmes, designs and projects meant for extension of alternate energy development programmes in the state.

10. To formulate and implement a broad-based energy conservation programme for conservation of energy at all stages, including extraction, conversion, distribution and consumption.

Research Priorities:

The agency initially plans to concentrate on the following priority areas:

(a) Energy Plantations - large scale and small scale.
(b) Organic wastes as energy sources.
(c) Combustion devices with improved efficiencies for domestic use such as kerosene stoves, wood-fired chulas etc.
(d) Bio-gas plants.
(e) Studies on rural energy consumption and needs in Gujarat.

(f) Conservation of energy

(g) Wind energy systems

(h) Solar thermal energy applications.

Policy for Sponsoring Research:

GEDA will sponsor research, development and demonstration programmes with various institutions - both public and private. While the agency will largely concentrate on the priority areas described above, it will also favourably consider outstanding proposals in other areas relevant to the State.

Communicated by : Dr. B.G. Desai, Devki R and D Engineers, Vasant Kutir, R.C. Dutt Road, Baroda 390 005.

INDIAN COPPER INFORMATION CENTRE

Calcutta

The activities of the Indian Copper Information Centre in the area of solar energy utilization are mostly related to development of solar water heaters employing copper based flat plate collectors for domestic, semi-industrial and industrial applications, in line with the objective of the Centre to provide technical information and advisory services in the effective and efficient use of copper. The research and development programmes in this area are supported by the CIPEC (Intergovernmental Council of Copper Exporting Countries, France). Department of Science & Technology, Govt. of India, R&D Institutions and industries. Salient features of the solar energy programmes of the Centre, which was started in the year 1973 are given below.

Design and Fabrication

Copper panelled solar water heaters, based on the original design developed by the Centre's counterpart in Australia and made available free of cost, was further developed with the view to suite Indian conditions and to reduce the total cost. Solar water heater units fabricated on this basis have been tested for performance for over two years at the National Test House, Calcutta. The tests have yielded satisfactory results and the panels showed no trace of leakage or corrosion even after three years.

Test Units

Following the successful completion of the first stage, the Centre has assisted the fabrication and installation of five units in one of the major hotels in Delhi for performance trial under actual service conditions. These units are being run parallel with units made of aluminium which have started showing signs of failure due to corrosion resulting in severe leakage within one year of service. It is proposed to set up additional units in due course.

Demonstration Units

Arrangements have been finalised for setting up one or two demonstration units at the Birla Industrial and Technological Museum, Calcutta. These units will be installed during 1981. This is essentially to create an awareness in the minds of the public on harnessing solar energy for heating water by a simple and efficient method.

It is also proposed to set up similar demonstration units in some of the universities and regional centres of the Solar Energy Society of India.

Research and Investigation

The Centre has sponsored a research project to study the relative effectiveness of various materials of construction and fabrication techniques in the manufacture of solar water heaters at the IIT, Madras. The research project would also study performance efficiency both under actual field conditions and simulated conditions and investigate problems arising out of corrosion of the material of construction under different conditions. The first phase of the project is expected to be completed by the end of 1981.

Future Programmes

Presently, the Centre is examining possibilities of assisting industries and other R&D laboratories in sponsoring demonstration cum research programmes for studying the feasibility of employing solar water heaters for meeting a part of the hot water requirements. Proposals are under consideration for assisting an industry in the southern part of India in setting up solar water heaters for supplying hot water to the canteen and metal finishing section. Similarly, the Centre also proposes to sponsor a project on studying the feasibility of employing solar water heaters in textile industries jointly with a research institute in the western part of the country.

The Centre would be happy to consider requests from educational institutions, research laboratories and industries for sponsoring/co-sponsoring/

undertaking developmental projects on copper panelled solar water heaters for domestic, semi-industrial or industrial application. Request for further details or proposals may be sent to the Director, Indian Copper Information Centre, 27-B, Camac Street, Calcutta 700 016.

Publications

The Centre has brought out a publication of solar water heater giving the salient features of copper panelled solar water heaters. A revised publication with additional information is under print and will be available from the middle of 1981.

Communicated by : Dr. L.R. Vaidyanath, Indian Copper Information Centre, 27B, Camac Street, Calcutta 700 016.

KARNATAKA STATE COUNCIL FOR SCIENCE AND TECHNOLOGY

Indian Institute of Science

Bangalore

The Karnataka State Council for Science & Technology (KSCST) was set up during late 1975 in an attempt to identify projects which promote the application of Science & Technology to the development problems of the State. KSCST has now sponsored over 250 projects and some of these are at various stages of implementation. A project on "Energy Planning for Karnataka", which was carried out in early 1977 with the idea of providing domestic connections to rural households and supplying non-metered electricity between fixed hours has very recently, in a somewhat similar idea, being implemented through the Bhagya Jyothi scheme.

Renewable energy projects such as solar driers for agricultural produce, solar cookers, solar refrigerators, solar dehumidifiers, solar pumps, solar stills, community bio-gas plants, gobar gas engines, sewage sludge gas plants, windmills, energy consumption pattern of villages etc., are in progress in the State Engineering Colleges under the KSCST's Student Projects Programme.

Community biogas plant:

The widespread diffusion of small-scale biogas plants in the rural areas suffers from two major drawbacks : (1) the poorest families do not own the cattle resources necessary to run biogas plants, (2) there are definite economies of scale leading to large biogas plants being more economical than small ones. It is in this context that the proposal of community biogas plants has been urged, although problems of dung collection, gas and sludge sharing, gas distribution etc needs further study.

The major energy requirement in rural areas is for cooking, and at present, this is met by non-commercial energy, mainly firewood. In order to preserve this rapidly depleting resource and at the same time enhance soil

fertility using natural compost manure, the KSCST constituted a Working Group. The task of this group has been to prepare a feasibility report on a village-scale community biogas plant as the basis of rural energy centre.

A detailed survey was carried out in six villages of Kunigal Takuk, Tumkur District to understand rural energy consumption patterns and energy resource availabilities. Based on this survey, Pura village, (about 360 population and 60 households) was chosen for the detailed feasibility study and has been completed with detailed estimates of costs and commercial viability, as well as a rigorous social cost-benefit analysis. In brief, an investment of Rs.60,000 is required for the 1500 cubic feet per day biogas plant, the gas-pipeline system, the biogas engine, generator, electrical distribution system, pumpset, ball-mill, building, overhead water storage-tank etc. This study will be followed up with the implementation of a community plant in Pura village.

Solar energy in sericulture:

Sericulture is one of the most labour intensive cottage industry in the State, employing nearly two million people in the private sector and twelve thousand five hundred people in the public sector. The three stages of operation - stifling, cooking and reeling - for processing silk threads require energy in the form of hot water. The private filatures use firewood, charcoal, paddy-husk or saw dust as fuel for the variousactivities that require heat. The Government-owned silk filatures and silk factories derive their steam and hot water from coal-fired boilers of old and antiquated design. It is in this context that KSCST has initiated a project to investigate the scope of solar energy applications in sericulture. Specifically, use of solar energy for (1) supplying hot water for reeling and (2) cooling and/or heating of buildings for rearing silk worms, grainage and for storing cocoons,are being explored. This project is largely funded by the Department of Science and Technology, New Delhi.

A survey of the energy requirements of filatures both public and private sectors has been completed. Based on this survey, an initial estimate of hot water requirements has been carried out. In addition the energy requirement for providing hot air for stifling and drying of dead pupae, in place of the conventionally used steam, has also been estimated. Flat plate type solar water heaters from BHEL and Solar Systems, Bangalore are proposed to be used.

A solar passive heating and cooling system based on the 'skytherm' technique is proposed for controlling the temperature inside the buildings used for rearing, grainage and storage of cocoons within 25 $\pm$ 3 °C throughout the year for a place like Bangalore. Skytherm airconditioning experiments are in progress and a new building of 9m x 4.5m has been designed and planned for erection at the Indian Institute of Science campus for further studies.

A control system for the operation of the solar water heater has been designed and is being tried out in conjunction with a single solar panel at the IISc premises and its performance is being evaluated. Also, it is proposed to erect the solar panels at the Government Silk Filature, Mysore and their performance will be monitored for an extended period to assess their feasibility.

Wind Energy Utilisation:

Till very recently, no windmill could be seen anywhere in Karnataka. One of the major reasons for the apparent lack of interest in wind energy is the significant variations in wind, over a daily as also monthly or seasonal time-frame. KSCST therefore undertook a project on the mapping of wind energy potential in Karnataka.

The study team has completed its work and final reports have been prepared. Based on the analysis of wind data collected from 22 meteorological stations spread over Karnataka, the working group has arrived at certain conclusions :

1. Annual average of windspeeds observed in the State are generally low for windmill applications except at stations like Bangalore, Bidar, Gulbarga and Raichur. where the annual averages are better than 13 km/h.

2. During the south-west monsoon, these stations receive faster winds, with monthly average speeds exceeding 20 km/h.

This preliminary study has highlighted the need for a number of specific tasks that have to be carried out before firm, location and application-oriented windmill recommendations can be made to the Government for purposes of implementation. Salient among these is to set-up wind measurement station in at least one of the relatively windier districts (Bangalore, Bidar, Gulbarga, and Raichur) to obtain a better estimate of the annual energy flux in the wind and also to ascertain the likely output that can be expected out of any windmill.

Prepared from: KSCST's Annual Report 1978-79, presented to the Fourth Annual General Meeting of the State Council.

KHADI AND VILLAGE INDUSTRIES COMMISSION

Bombay

Amongst renewable sources of energy, biogas energy system is now becoming popular. There are more than 70,000 biogas plants in operation today in India, and many developing countries have decided to have such plants which promise fuel, manure and sanitation with indirect contributions towards maintenance of soil fertility, savings in the transportation of fertilizers, fossil fuels and their consumption.

Historical Background

Research work on digestion of sludge was done during the war period between 1900 to 1942. The first such big sewage plant in India was put into operation in 1937 at Dadar, Bombay. The interest then grew in extending this type of system for the disposal of village wastes especially cattle dung. Dr. S.V. Desai and Biswas from I.A.R.I. conducted laboratory experiments between 1937 to 1946 and published a valuable data on the anaerobic digestion of cattle-dung.

Prof. N.V. Joshi patented a design of biogas plant in 1946. It almost resembled the experimental digester used by Dr. S.V. Desai for his investigation. However, this design did not succeed in the field, due to some operational difficulites and high capital cost. Some of these digesters also burst.

Simultaneously Mr. Y.N. Kotwal, and Borker of Dadar sewage purification plant were working on the addition of urine and they found that it helps in the faster fermentation of cattle-dung.

The work of Dr. S.V. Desai, Prof. Joshi and Kotwal did not give any practical design of biogas plant. However, the valuable data collected by them, helped Shri J.J. Patel to evolve a most practicable design of biogas plant in 1951 which was known as Gramlaxmi. This design cost Rs.1800/- (Rs. Eighteen hundred only) and used to give 200 cft of gas/day as compared to 20 cft of gas obtained from the plant patent by Shri Joshi and having the same cost.

The special features of the Gramlaxmi - I design were :

- Gas holder and digester form one unit instead of separate digester and gas holder as followed by Dr. Desai and Joshi in their design.

- It was possible in this plant to follow a continuous system of digestion, taking into considertaion the daily accummulation of cattle-dung.

- Yet another advantage of this design, was that the feeding was done under gravity and the fermented residue was also collected under gravity without any extra effort.

On similar lines Mr. Satishchandra Dasgupta and Swami Vishwakarmanand developed biogas plant designs having similar features as that of Gramlaxmi except for the materials for digester. They used split bamboo instead of masonry work for digester. The gas holder however was guided by pulleys instead of central guide system. This was done to create negative pressure in order to get more gas.

Dr. C.N. Acharya, and his colleagues from I.A.R.I. happened to see such plants in West Bengal and they adopted the same design. Dr. C.N. Acharya has published a book giving valuable data regarding rate of gas production in various seasons and effect of pH, temperature, etc. on the rates of cattle-dung fermentation in such plants.

Gramlaxmi-I design was subsequently modified by using pulley-system for gas holder as well as water jacket system. This was named as Gramlaxmi-II, which was an utter failure due to the uneven movement of the gas holder and accumulation of thick scum which prevented the gas entering into the gas holder. It was also observed that the masonry used for water jacket system absorbed the gas to a considerable extent.

Based on this experience, Gramlaxmi-II was replaced by Gramlaxmi-III which had two chambers and a central guide system for gas holder which gives 3" water column pressure without any attention. The gas holder is free to rotate

around the central guide pipe to break the scum. The existing design adopted by Khadi and Village Industires Commission, is the Gramlaxmi-III, design which has been functioning popularly in India and abroad. The Planning Action and Research Institute, Ajitmal, Etawah, had adopted I.A.R.I. design which was subsequently discharged and they now use the Khadi and Village Industries Commission design (Gramlaxmi-III).

The National Engineering Research Institute, Nagpur has conducted experiments on the IARI design of biogas plant mainly on cattle dung fermentation at various loadings as well as fermentation of night soil. It was confirmed from their studies that addition of night soil helps in faster digestion of cattle dung. They have also published data regarding recirculation of gas for higher rate of gasification, effects of volatile acids accumulation on the rate of fermentation of cattle-dung.

Major Achievements

1. The Gobar Gas Research and Development Centre, established in 1962 at Bombay undertook the basic work regarding improvements in the design of vertical gas plants. The design was standardised with respect to the positioning of feed pipe, outlet pipe, central guide frame, design of gas holder, gas outlet pipe and flexible connections etc.

2. Gas Burners : Due to the presence of 45% CO_2 and limited quantity of gas available for use, suitable aerated burners which give 55 to 60% efficiency were developed. It was therefore possible to reduce the per capita consumption of biogas from 12 cft. to 8 cft. per day.

3. Gas Lamp : A low pressure biogas lamp, first of its kind, to use pressure silk mantle was developed. It eliminates costly preformed mantles and gives 5 times better illumination than the then coal gas lamps in use for biogas.

4. Horizontal Gas Plant : It is very difficult to dig when one comes across rock or high water table, especially in coastal and delta areas. The horizontal plant which resembles a septic tank but having a slope at the top for efficient

accumulation of gas in the gas holder was developed. The rate of gasifiction in such plants has been found to be almost the same as that of vertical plant.

5. Engines :

Diesel engines of 5 to 6 hp. (Vertical and Horizontal)have been converted for biogas. These engines use 20% diesel and 80% biogas. Such engines suitable for irrigation purposes, running chaff cutter, flour mill and supply of electricity for small villages etc.

Petrol engines of 1.7 to 2.5 hp. have also been converted to biogas. These engines develop 80% of the rated power of the petrol engines. To start with, the engine is run on petrol for about a minute and then it is switched to biogas. Reduction of CO_2 in the gas by 10-15% helps in attaining the rated power of the petrol engine.

6. Fermentation Studies : Studies on the fermentation of rice husk, neem husk, castor cake for gas production have been undertaken and these materials in conjunction with cattledung have shown promising potentialities for their use in community gas plants.

7. Mixer for Cattle-dung : Mixers of various sizes for cattledung slurry have been developed. These mixers when made out of ferrocement become resistant to corrosion, thus increasing their life.

8. Protection of Gas Holder from Corrosion : It has been found that epoxy coal tar paint gives better protection to gas holder than enamel paints. However, the cost of such paint is three times the cost of enamel painting. Another process of using ordinary coal tar and PVC film has given promising results. It is also cheaper than enamel painting. However, the problem of poor adhesion between PVC film and coal tar has to be overcome.

9. Design of Gas Holder using Light Materials : Taking into consideration the huge quantity of steel required for biogas plants, efforts were made to choose cheap alternate light weight material. Gas holder made from galvanized

sheet has been found to be of great promise. The design is very simple. The pressure of the gas holder can be adjusted to 3" water column pressure or even more by extra weight in the form of ordinary sand on the top of gas holder. This also eliminates the difficulties faced while putting the gas holder into the digester chamber and vice versa. Moreover, such system will have employment potentialities in villages as it almost eliminates use of electric/gas welding. Similar type of gas holders can be made using rigid PVC sheets or high density polythene. Such gas holders also give satisfactory performance from rusting problems and transport.

10. Collapsible Gas Holder : Collapsible gas holders have been developed using leather cloth and nylon reinforced PVC. A special design for the adjustment of pressure has been evolved. The advantages of such gas holder are, : (1) Light in weight, (2) easy to transport, and (3) cheaper than the existing gas holder.

11. Industrial Burners : Burners for small industrial units such as soap making, heating water for laundry, ignition of coke in foundry, melting of paraffin wax, and also burners for laboratory use have been developed.

On-Going Research Projects

The capital investment on biogas is increasing day by day. The technology therefore cannot be made use of, by the marginal farmers. Cement and steel are the materials of importance required for biogas plants. Morever, maintenance of mild steel gas holder for rusting is also a problem. In view of this, efforts are being made to design a suitable (family) plant which will almost eliminate the use of mild steel and cement. Prefabricated plant, if supplied to the people will help in reducing their hardships in the collection of the materials such as cement and steel. A recent work, on gas holders made from closely woven hesian cloth, nylon cloth etc. have given promising results.

Another project on community biogas plant is under investigation with high rate of digestion by heating the digester, mechanical stirring of digester content etc. It is also proposed to utilise other agricultural wastes, such as

groundnut shells, castor and neem cakes, bagasse etc. This will avoid total dependence on the supply of cattledung which may not be available in full quantity throughout the year. The success of community gas plant will also depend upon satisfactory distribution of gas, without much capital investment. For this purpose it will be necessary to develop : (1) A suitable gas meter, (2) compression of gas with a suitable adsorbent. Pelletisation of manure by enrichment with nitrogenous cakes or fertilisers will enable the farmers to use fertilisers, scientifically as well as economically. These efforts will also enable to maintain the fertility of the soil.

Development of commercial burners has been undertaken to help some of the agro-industries which could have biogas as a source of energy.

The project on suitable gas plant design for cold regions has been undertaken due to the slow rate of gas production during winter in the northern part of the country. Efforts are being made to tap solar energy for heating the slurry and digester and suitable solar slurry heaters are being developed.

Projects on fermentation kinetics and environments are of equal importance in reducing the cost of biogas plant. Parameters such as temperature, C:N ratio, addition of suitable nutrients in the form of nitrogenous cakes to accelerate the process of fermentation etc. are being studied.

Also suitable biogas engines which could be started and run on biogas are being developed.

Laboratory and Testing Facilities

Except for the microbiological tests, the Gobar Gas Research and Development Centre, Bombay, has laboratory and testing facilities for gas appliances as well as raw materials used for fermentation. This centre has also helped in the formulation of ISI specification for gas appliances.

Teaching and Training Programme

Since its inception in 1962 about 150 candidates have been trained required for the implementation of biogas programme. This work however, does not form the regular programme of this centre at present.

Consultancy Service

This centre has been rendering consultancy service on the utilisation of various agricultural wastes for biogas. To mention a few, the following organisations are the recipients of the technology transfer :

1) Modern Foundries - Ahmednagar
   Ignition burners for foundry and drying of manure.

2) Panjarpole Gorakshan Sanstha - Ahmednagar
   Burner for bottle sterilizer.

3) Kora Gramodyog Kendra, Borivli, Bombay
   Soap burner of 300 cft/hr capacity.

4) Thana Power laundry - Bombay
   Development of water heater with 80% thermal efficiency.

Expertise Available at KVIC

Designing of biogas plants using cattledung, rice husk, castor cakes, neem cakes, pig wastes, human excreta, etc. and utilisation of such gas for various small industrial applications.

Future Programmes

1) Development and improvement in prefabricated family biogas plants using cheap local materials.

2) Community gas plants as a total energy system for villages.

Also studies on :

a) High rate digestion with stirring, carrying out fermentation at thermophilic range and utilisation of other agricultural wastes including water hyacinth.

b) Gas distribution system using simple gas meters and cement asbestos pipes in place of G.I. pipe. Compression of gas in cylinders with suitable adsorbents.

c) Enrichment of manure and its pelletisation/briquetting.

d) Use of solar energy for biogas plant for heating and stirring.

3) Development of Commercial gas appliances : Small baby boilers, ovens, incubators, cold storage and other equipments required for running agro-industries.

4) Gas Plant for Cold Region : A suitable design which will reduce the loss of heat from the digester.

5) Fermentation Kinetics : Studies on fermentation including studies on enzymes and mutants, helpful in methane gas production.

References

Biogas Achievement and Challenges by M.A. Sathianathan, Association of Voluntary Agencies and Rural Development, New Delhi, 1975.

Communicated by : Mr. G.L. Patankar, Dy. Director, Gobar Gas Research and Development Centre, Khadi and Village Industries Commission, Kora Gramodyog Kendra, Borivili, Bombay.

NORTH EASTERN RAILWAY

Gorakhpur

Two projects pertaining to renewable energies were undertaken during 1978.

1. Development of a portable low cost household solar water heater; and

2. Disposal and recycling of human kitchen, vegetable and animal wastes through Bio-digestion.

The work on the former has been completed and a prototype costing about Rs.900/- and giving 70 litres of hot water the year round, except on rainy days, has been working satisfactorily for more than a year. The prototype includes the storage within the collector itself and is completely portable. It is provided with an insulated cover, which works as a reflector of an average quality during the day and insulates the collector at night. Water is used primarily for bathing next day morning. The minimum temperature obtained has been over 35°C in the morning when the minimum ambient temperature was 6 to 7°C.

Bio-gas waste disposal & recycling systems

Disposal of human wastes is a particularly vital problem in India. The existing toilet systems do not recycle the mineral and residual energy resources in the wastes. Considering the national and social importance and the potential of using biodigestion systems for disposal of domestic wastes a four-phase project was taken up.

Phase I: A low non flushing (aqua-) privy which is easy to construct and maintain and from which the effluent can be recycled as manure.

Phase II: A biodigestion plant (1.5 cum biogas/day) as a household waste disposal unit, to which wastes from toilets and kitchen (and available vegetable and animal wastes) can be fed.

Phase III: Medium size (3 cum biogas/day) and large size (6 cum biogas/day) biodigestion plants to work with community latrines.

Phase IV: Larger size biodigestion plants to work primarily on water hyacinth weeds and to which wastes from toilets and kitchens etc. can also be added.

The development of suitable toilet systems, which will also deal with other domestic wastes, has been considered in two parts.

- Development of the disposal system based on bio-gasification of the wastes.

- A suitable seat design to go with the disposal system.

The usual Indian design of biogas plants, having a floating steel gas-holder was considered unsuitable because of:

1. Its high cost.
2. Requirement of scarce steel.
3. Difficulty of maintaining steel tank with human wastes.
4. An additional water seal is required around the tank to avoid exposure of night soil in the annular width.
5. Thermal losses from the top of steel tank has been known to be very high, which would significantly reduce the rate of biodigestion.

The alternative design which is in common use in China for various type of wastes, namely the integral masonary chamber was found to be ideally suited because it avoided the various problems of the steel drum plant and also cost 40 to 50% less than the design with the steel drum.

The common design of the Chinese type biogas digestor is 10 cum which is too large for domestic use. The smaller size from which biogas may be collected in a worthwhile quantity, would be 4 to 5 cum giving 1 to 1.5 cum biogas per day. Accordingly, a pro-rata design of 4 time digester size was worked cut and a prototype was experimented with wastes from toilets as well

as from kitchen animal and vegetable wastes. The prototype digester gave satisfactory results particularly with regard to the toilet wastes. The usual amount of water used in India for ablution was found to be within the permitted dilution range for digestion.

Based on these experiments detailed designs have been finalised for the following biodigester units:

1. For individual toilets A digester of rectangular shape from which biogas is not collected. It can serve upto 10 persons.

2. Regular bio-digesters of size 4 cum, 10 cum and 20 cum - The former one can be used either as a household disposal unit for a family to deal with not only human but also other types of domestic wastes, or it may be used for community toilets to serve upto 50 persons. The other two designs are for community toilets to serve upto 100 and 200 persons respectively.

The seat design has been finally adapted from that of the Gandhi Smarak Nidhi, Pune. It has no water trap thereby obviating the need for flushing and has a 45° slope so that the wastes do not stay. The water seal is provided by extending the tail end into the digester.

With the combination of digester and the seat designs mentioned above, it has been possible to complete the development work on the three phases of the project. Toilet designs have been finalised as below :

1. Aqua privies as individual units - In this case no biogas is collected and affluent may be used as manure as in the case of 'Gobar gas plants'. The old designs of aqua prives have been revised by shifting the digester tank from below the seat to the rear. This has reduced the cost per latrine to only Rs.1500/- compared to Rs.2200/- for the old design. Further, the existing 'dry type toilets' can be now converted into sanitary type at a cost of only Rs.600/- each. About 2000 aqua privies have been constructed to the new design, saving nearly Rs.20 lakhs.

2. Community latrines - The first set of community toilets were commissioned on 2 October 1980 at Gorakhpur Railway Station with 12 toilets served by 2 biogas digesters of 20 cum size each. These are being used by over 400 people daily and the operation has been extremely satisfactory. The effluent is completely odourless and has the desired pH range. Biogas is being produced in good quantity and is being already used in a tea stall on the railway station platform. The biogas is used for 6 to 8 hours daily saving over 6 kg coal per day. The output of biogas is increasing as the summer season is approaching. The use of manure is also being considered though, at the railway station due to space limitation, the effluent is at present being let out into the drain.

Due to the success of the first set of experimental community bio-toilets, similar units at six other railway stations, where a large number of new passengers misuse the railway area, are being planned. In the meantime, the experimental unit at Gorakhpur station is being run as a demonstration project for engineers and others interested in the subject.

Future Programmes

1. It is proposed to construct aqua privies to the revised designs in much larger numbers especially to convert to "dry type toilets'.
2. Perfecting the specifications for community latrines, working with bio-digesters and extending their use to more places.
3. Development of biogas digesters of 50 cum size to work primarily on water hyacinth as mini biogas-cum-organic manure plants, to which domestic wastes can also be added.

A number of drawings and instruction sheets have been issued. The work done has been summed up in a paper "Bio-latrines - a latrine system that India can afford", at the National Seminar on "Energy Conservation" held at New Delhi by National Productivity Council.

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ORGANISATION FOR RURAL POOR

Windmill Project

GHAZIPUR

The project came into being during 1977 where windmills when developed and manufactured. These windmills can be used throughout the year as an inexpensive and convenient water lift device energized by the windmill for irrigation. After three years of experimentation, windmills are being manufactured for commercial sale since 1980.

This horizontal axis windmill "12 PU 500" is entirely built out of materials which are readily available in the local markets. The basic structure is steel, nylon for bearings, wood and steel pipes. The total weight of the windmill is approximately 400 Kg. The height of the tower is 7 m and the diameter of the rotor is 5 m. The project has developed smaller version of this windmill (12 PU 350) which is being field tested. Under the same circumstances the expected discharge of this windmill is about 50% of that of the 12 PU 500. Since these windmills have been developed especially for low wind areas, like Ghazipur district, the cut-in windspeed of the windmill is only 3 m/s (11 km/h) for a lifting head of 6 m. (Cut-in speed is the lowest windspeed at which the windmill starts working.) The whole top structure can turn freely around the central tower pipe and the tail keeps the rotor in the wind direction. For protection against the high wind velocities or storms, the head assembly along with the rotor will get unlocked automatically from the tail with the help of a small vane behind the rotor at windspeeds over 10 m/s. The unlocked head construction turns out of the wind and is locked to the tail at a position almost parallel to the wind. After the storm has passed the rotor has to be put back in the wind by the farmer.

The windmill drives a piston pump through a crank-connecting rod mechanism. The pump is made out of steel. The piston is made of wood with a leather valve. When the refilling capacity of an open well is more than 30

cubic m/h, boring is needed. In case where a tube well has to be installed, the pump is directly connected with the tube-well.

The table below shows the discharge capacity of the 12 PU 500 windmill with a total head of 6 m and pump with a diameter of 150 mm, and stroke of 240 mm.

Table : Discharge capacity of 12 PU 500 Windmill.

Velocity of the Wind			Discharge	
(m/s)	(km/hr)	RPM	(cubic m/h	(L/Sec)
2-3	7-11	21	36	1
3-4	11-14	31	5.4	1.5
4-5	14-18	42	72	2
5-6	18-22	55	108	3
6-7	22-25	70	144	4
7-8	25-29	86	188	5
8-9	29-32	102	21.6	6

Whenever there is wind of over 3 m/sec, the windmill will start pumping water continuously. The windmill pumps the water into a storage tank (size 10 x 10 x 1.5 m). Out of the storage tank the farmer can irrigate his crops with the help of a syphon at his convenience. The syphon gives a flow of approximately 4 litres/sec which facilitates irrigation with high efficiency. The storage tank can also be used for fish rearing and for the cultivation of blue-green algae which can be used as manure. The monthly assessed output of the windmill (in Ghazipur, UP) is as follows (in cubic m):-

Jan	710	July	1440
Feb.	845	Aug.	1485
March	1295	Sept.	1300
April	1705	Oct.	585
May	2185	Nov.	335
June	2060	Dec.	550

The U.P. Government has exempted the windmill from sales tax with effect from 1 Jan. 1981. The life of windmill is estimated to be 15 years. There will be no recurring costs when the windmill is operating. Repair and maintenance costs are negligible. From the total cost of a windmill, (considering its life time and output) it is calculated that the cost price of 1 cum of water pumped by a windmill will be competetive with that of water pumped by a 5 HP diesel pumpset having the same duration of lifetime and running hours. The marginal difference in cost prices is mainly due to the fact that a windmill does not have any recurring cost (wind is freely available) and a diesel pumpset has very high recurring cost (fuel).

The windmill is particularly suitable for water supply to the over-head tanks for drinking purposes in villages and remote areas. Even in cities and industrial areas, the windmill has a great potential for this purpose as they can be installed on roof tops of high buildings and also on top of the over-head storage tanks themselves.

The Project is non-profit organisation which works basically for the small and marginal farmers to whom windmills are sold on priority basis. The Project also helps these farmers to arrange a loan or subsidy for purchasing the windmill.

Government of India have brought windmill on par with the conventional devices of irrigation like diesel and electric pump by declaring subsidy on windmills to the extent of 25% for small farmers and 331/3% for marginal farmers. Further, the Govt. of UP have also declared the subsidy to the extent of 50% for the marginal farmers for Ghazipur district.

Current Activities

An electrical generating unit capable of functioning at wind velocities as low as 2 to 3 m/sec (7 to 11 kmph) is being developed. The device will charge a battery bank and supply AC through an inverter at 250 volts 50 hertz., for household and industrial purposes. It is expected that the cost of this windmill will not be more than Rs.15,000/- inclusive of the battery bank.

Plans for Future Work

1. To develop 5 KW windmill on the same line on the horizontal axis design for generating electricity as well as for multipurpose agro-industrial applications.

2. To develop vertical axis (Darrieus type) windmills for generating power with capacities of 8 KW and beyond, with hollow extruded aluminium blades.

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STATE PLANNING INSTITUTE, U.P.

Planning Research and Action Division

Lucknow

The State Planning Institute has been concerned with serious energy problem in rural areas and has planned for studies and work in three directions :

1. Studies are being undertaken to assess quantitatively the existing pattern of demand and supply of energy in the rural areas as related to various socio-economic and technological factors with a view to obtain projections for the future and thus provide a data base for formulation of appropriate energy policies.

2. The Institute is developing technologies of renewable energy sources appropriate for use in the rural areas.

3. The Institute also proposes to work on methodologies for conservation of energy in agricultural and industrial applications.

1. Rural Energy Surveys

The Division has taken up a comprehensive study of rural energy system in Uttar Pradesh. This study covers five major regions of the State having different topogrpahic and climatic conditions with an aim to study the present energy requirements in five sectors viz. domestic, agriculture, animal husbandry, rural industries and transport. The study aims to highlight, apart from quantification of energy needs, the patterns of inflow and outflow of energy from one sector to another. It is also proposed to project the energy demand of the rural sector to the year 2000 and to indicate different locally available energy sources likely to meet this demand with the development of appropriate technologies. The data collection for five villages in two regions has been completed and results are expected to be compiled and analysed by 1981. Work of data collection in eight more villages in the other three regions will also be taken up subsequently.

2. Appropriate Technologies

2.1. Biogas

The State Planning Institute has pioneered the design and construction of low cost family size biogas digesters of sizes 2 cum to 6 cum. The designs for sizes upto 15 cum. are being evolved. The drumless design is 30 to 50% cheaper as compared to previous steel drum type of biogas digesters commonly known as KVIC type. The State Planning Institute design can be located wholly underground thus saving space and decreasing susceptability to temperature variation during winters. About 4500 plants of this design have been constructed in U.P. during the past two years and are working successfully. A target of constructing one lakh plants during the period 1981-85 has been made.

The Institute undertook the construction and operation of a community biogas plant for a small rural community of Fateh Singh Ka-Purwa in Bhagyanagar block of district Etawah. The plant supplies cooking gas for all the families of the village. With adequate supply of cattle dung, it also provides for other services namely electric power for lighting and running irrigation pumps and motive power for operating flour mill, thresher, chaff cutter etc. The Institute is constructing seven more such plants (five in Uttar Pradesh, one in Bihar and one in Himachal Pradesh) under the All India Coordinated Biogas Project, financed by the Department of Science and Technology, Government of India. An additional number of 20 such plants is proposed for construction during 1981-82 under the same project. With development of proper organisational support for this programme, finances are expected to be available for 100-200 more such plants during the Sixth Plan Period. The Institute will be involved in the construction of such plants in the Stages of Punjab, Haryana, Rajasthan, Himachal Pradesh and Bihar in addition to Uttar Pradesh. The Institute has designed and provided a number of new features in these plants in order to improve generation of biogas and ensure trouble free performance.

The Institute is working on alternative feed material for biogas plants in order to reduce the present dependence on cattle dung. Experiments underway at the Institute's Gobar Gas Research Station at Ajitmal (Etawah) have shown possibility of use of water hyacinth, corn stalks and other agricultural wastes for use as feed material.

2.2 Solar Energy

The Institute initially became interested in solar energy as a means for providing a low cost device for raising the temperature of biogas slurry in the digesters for increasing methane generation specially during winters. The heating systems developed at Gobar Gas Research Station, Ajitmal are technologically sound but initial costs have to be reduced to make them economically viable.

The Institute's plan includes work on a few selected aspects of solar energy during the Sixth Plan namely :

1. Flat Plate Collectors.
2. Domestic solar cookers.
3. Low cost solar energy storage systems.
4. Small irrigation pumps powered by photovoltaic devices.

2.3 Wind Energy

Experiments regarding utilisation of wind energy for operating irrigation pumps have been carried in Ghazipur by the Organization for Rural Poor, in which State Planning Institute has also, been associated. It is proposed to continue this work further with a view to improve the existing technology.

2.4 Draught Power

Bullock power provides an important source of energy for transportation and other agricultural use in the rural areas. The Institute had conducted experiments on improved bullock carts. An irrigation pump suitable for operation by a pair of bullocks and operating through an open well or a boring has been developed and is now in the final phase of practical testing.

2.5 Total Village Energy Concept

Studies are being initiated for the fulfilment of a major portion of energy need of a village community through utilisation of renewable energy sources.

One village has already been selected for this work in consultation with the Department of Science and Technology, Government of India and work therein will start shortly.

2.6 Energy Conservation

Studies planned at the Institute in this area include increasing the efficiency of wood and charcoal stoves as also efficiency of biogas burners. Energy Conservation studies in industrial applications are also planned for which proposals are being discussed.

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