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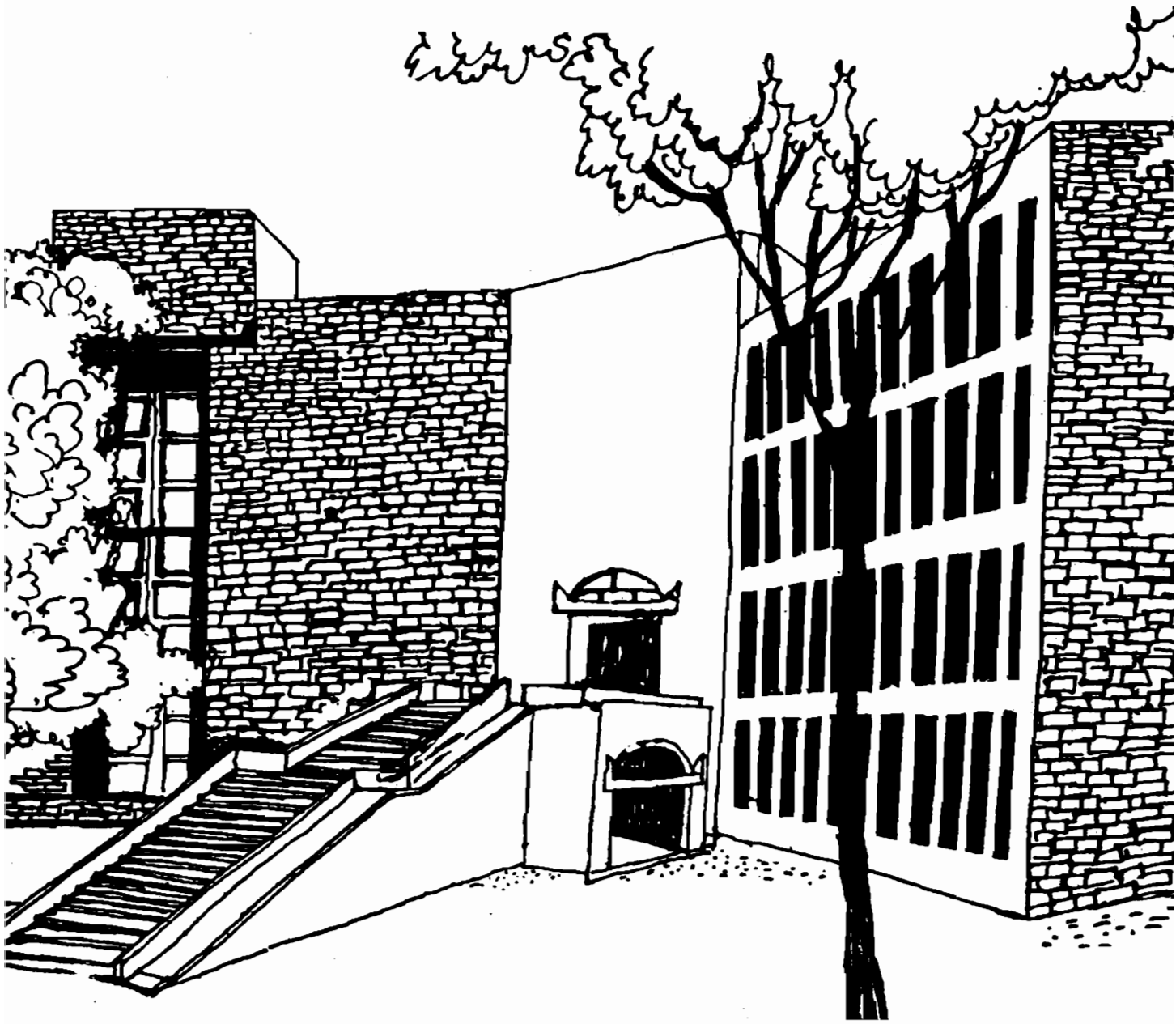

SOLAR ENERGY TECHNOLOGY: RESEARCH & DEVELOPMENT IN INDIA

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ABSTRACT

Solar Energy is a direct and perrenial energy source . It is non polluting and is available freely. The technology of converting solar energy into heat and utilizing it for various applications can now be commercially exploited. Solar Energy is received in the form of light and heat radiation. The radiant energy of the Sun can be converted into thermal, electrical, mechanical energy etc. but of all these types of energy in solar radiant energy the thermal conversion mode is the easiest and most convenient.The sun energy can be used to meet the thermal requirements in almost all the temperature ranges in every sector of national economy. The objective of the Solar Thermal Programme of The Department of Non Conventional Energy Sources is to develop and promote use of technologies for conversion of solar energy into thermal energy for supplementing the ever increasing demand for thermal and electrical energy in the developing economy.

1.0 Introduction

Solar Energy is the oldest form of energy , it is ample and as human lives are measured it is everlasting. In India, Solar energy was first harnessed during the early fifties, but did not gain much impetus. During recent years, increasing attention has been diverted towards renewable sources due to the sharp increase in oil prices, difficulties in producing and transporting increasing amounts of fossil fuels, supply uncertainities and environmental degradation caused by conventional fuels.

Solar energy is a major focus of Non Conventional Energy Sources. It has applications in all sectors and is capable of supplementing existing sources of energy. It plays a pivotal role and has long been a part of the Indian way of life.

A number of reputed national institutions are involved in doing research and putting up field demonstration units to popularize non-conventional sources of energy.

The Commission for Additional Sources of Energy has taken up projects for the establishment of production facilities for solar cells, solar thermal systems and various other renewable energy devices. Today, India is capable of making solar photovoltaic devices and systems, solar water heating systems, solar crop dryers, solar stills etc.

Inspite of all this, there is a great need to build up a country wide infrastructure for production, distribution, sales and servicing of renewable energy systems and also to promote awareness of the role and potential of renewable energies and the importance of energy conservation.

The solar energy utilization devices, in general, are of three types, (i) utilization of heat from the Sun, (ii) conversion of solar energy directly into electricity, (iii) photosynthesis and biological conversion.

The present paper highlights the importance of solar energy by cataloging various research investigations and field demonstration trials which in their turn have created public awarness regarding these renewable energy sources.

2.0 Economic and Financial Constraints

2.1 One of the most important constraints in the wider utilization of renewable energy sources is the high initial cost of the systems. At present, a solar device may cost more than a product based on conventional fuel. This acts as a deterrent to the potential users of renewable energy systems. On the other hand, the low level of production inhibits any cost reduction. This has become a vicious circle.

2.2 These problems can only be overcome through technical improvement, material and manufacturing development and a package of fiscal and other promotional measures.

2.3 Incentives and subsidies introduced at the initial stages will help the new and renewable sources to become economically competitive.

3.0 Research and Development of Solar Thermal Energy

Despite various incentives and subsidies, the renewable energy sources have not been fully exploited. Thus, it would be desirable to concentrate on ways and means of minimizing the use

of conventional energy by supplementing it with new and renewable sources of energy.

India has plenty of sunshine and solar energy can provide the best alternative to meet the thermal requirements in almost all the temperature ranges as can be seen from the following table .

TABLE 1

Temperature range	Application
Low grade heat (below 100^{0} C)	Water heating for various applications, air heating, drying, refrigeration, space heating, water desalination, pumping, etc.
Medium grade heat ($100-300^{0}$ C)	Cooking, steam generation for industrial applications, drying, refrigeration, power generation, water desalination, air heating for industrial applications, pumping etc.
High grade heat (above 300^{0} C)	Power generation

The Department of Non Conventional Energy Sources has promoted and funded research and development activities in the area of Solar Thermal Conversion through various Universitites, National Laboratories, with a view to developing newer materials and efficient systems and devices, improving reliability and performance of the systems and reducing costs. These research and developmental efforts include collection of basic metereological data like isolation, wind velocity, rainfall, relative humidity at various locations in the country which are the key factors for effective utilization of solar energy.

The thrust areas, in solar thermal energy conversion, include development of materials for efficient collector system, development of advanced collectors for medium temperature and high temperature output, development of solar refrigeration, air-conditioning systems, development of heat storage system and studies on system engineering.

The Eighth Five Year Plan document has outlined the importance of research and demonstration and field trials in creating public awareness towards renewable energy sources.

The Advisory Board on Energy has suggested that besides increasing the R & D efforts, a large number of systems may be installed through the demonstration programme as well as the extension programme of private users on a cost sharing basis. The Board has also recommended that the facilities for soft loan finance may be provided for users of such systems. The Government has recently introduced additional subsidies and incentives for the promotion of Solar Thermal Systems. Hundred percent subsidy is now available for installation of Solar Thermal Systems on pubic buildings where the cost of conventional fuel and energy is paid from the consolidated fund of India. This has aroused considerable interest from various public and private industries and establishments like hotels, textiles, hospitals etc. With this it is hoped that the Solar thermal programme will pick up and assume unprecedented proportions.

In the area of Solar Thermal Power Generation, two experimental solar thermal plants based on point focussing and line focussing collectors coupled with steam turbine have been installed,

commissioned and are working satisfactorily in Saljipally village near Hyderabad and Solar Energy Centre, Gwalpahari, respectively. Storage of thermal energy is of great importance in view of intermittent and diffused nature of solar energy. Materials and methods for thermal energy storage are being investigated through R & D projects funded to Punjab University, Chandigarh.

The overall objective of the Solar Thermal Programme is to develop systems through R & D activities, put up field demonstration units to collect performance data under actual field conditions and later on commercialize the systems for large scale utilization through an extension programme.

4.0 Solar Thermal Extension Programme

4.1 On realising the capability of low grade solar thermal systems /devices in saving conventional fuel by their large scale utilization in domestic, commercial and industrial sectors, a cost sharing scheme was introduced in April 1984. The percentage of investment sharing for the 1989-90 financial year is given in Appendix I.

4.2 Solar water heaters, Solar timber kilns, Solar air heaters/Solar desalination systems (Stills) and Domestic solar water heaters are the devices available to users under this scheme. The achievements during the 1989-90 financial year in the utilization of theses systems/devices are given in Appendix II.

4.3 Solar water heating systems are in great demand in the industries like dairies, canteens, hostels, hospitals etc. Large number of systems of capacity ranging upto 1,20,000 lpd have been installed in the country. According to the performance reports

submitted by the beneficiaries where these systems are saving electric power, the pay back period is 4-5 years, and where the industrial oil is saved the pay back period is 6-7 years.

4.4 Use of solar energy is also becoming popular in the country for drying of items like agricultural produce, fruits, tea, rubber etc. During 1989-90, 8 tonne per day capacity dryer for drying pepper has been installed in Palghat. Rubber Research Institute , Kottayam, has successsfully used solar dryer for drying rubber sheets.

4.5 Under the Solar Thermal Extension Programme, till December 31st, 1989, 2490 Solar Water Heaters, 4174 Domestic Solar Water Heaters, 36 Solar Air Heaters/Dryers, 39 Solar Timber Kilns and 7683 Solar Stills have been installed. A total of 1,19,471 m^2 collector area installed in these systems is capable of generating 80.64 million KWhr thermal energy equivalent per annum. Statewise position of systems intalled upto 31.12.89 is given in Apendix II.

4.6 The performance of Solar Thermal Systems installed under the extension programme is evaluated through the survey conducted by the Regional Offices of the Department and the independent agencies like National Productivity Council, Indian Association for Advancement of Science etc. The "Technical Committee on specification of the solar thermal systems" constituted by the Department reviews the filed feedback reports, survey reports and also the latest developments in the areas regularly. The specifications for the solar thermal systems are revised, based on the recommendation of this committee and are incorporated in

Extension Programme . On the recommendation of the Committee, DNES has been able to standardize the solar collector designs and materials. The conventional components like pumps, motors, controls in the solar system are being reduced and/or eliminated to increase the reliability. As a result of improved system design solar water heaters upto 3000 lpd capacity are now working successfully on thermosyphone.

5.0 Solar Cooker Programme

The Department of Non Conventional Energy Sources launched an investment sharing scheme on 'Solar Cookers' in 1982. Under this programme the department shares 33 1/3 % of the cost or Rs. 150/- (whichever is less) with the user on the purchase of the family size solar cooker. As a result, over 1,40,000 solar cookers have been sold. On an average, regular use of family type solar cooker saves 2 Kg. of wood per day or approximately 600 Kg. of wood per year. Thus the solar cookers uptil now if daily used are capable of saving 84 million Kg. of wood per year. Community solar cookers for cooking meals for groups of people have also been developed and their working has successfully been demonstrated. These cookers are now available to the institutions, organisations for meeting their cooking energy requirements where the share of the Department is 33 1/3 % of the cost or Rs 1050/- whichever is less. In order to protect the consumer interest and for easy repairs and maintenence, standard specifications have been laid down for solar cookers.

6.0 Solar Energy for Dairy Development

In order to promote the agricultural allied and ancilliary activities assistance was also extended to small and marginal farmers and agricultural labourers to purchsae milch cattle. The purchase under SFDA, and MFAL schemes was heavily subsidised. Apart from these incentives, the Government has also attempted to introduce solar energy to improve the dairy units efficiency. A number of demonstration programmes have been launched by the Department of Science and Technology. These solar installations propose to save a substantial amount of conventional fuel and to improve the profitabilty of dairy units.

7.0 Solar Refrigerators

Efforts have been initiated for indigenous development of small size refrigerator by funding a project jointly to IIT Delhi, IBP Co. Ltd., Bombay and Solar Energy Centre which will be a boon to the rural areas. Similarly efforts are also being made jointly by Sardar Patel Renewable Energy Centre , Vallabh Vidyanagar and the Solar Energy Centre for developing a small refrigerator based on zeolite. These technologies are going to contribute significantly for providing low temperature storage facilities for life saving drugs and preservation of agricultural and dairy products in rural areas. Solar powered refrigerators also enable the storage of vaccines and thus contribute to the mational immunization programme. About 20 PV powered small refrigerator systems have been installed in various parts of the country for field trials.

8.0 Solar Energy Centre.

This Centre has been established to promote applications of solar technologies through product development, systems engineering and development, testing and certification of materials, field demonstration testing and certification of solar components and systems, material components, product and system standardization, arranging training courses and seminars and providing the necessary links between R & D organizations and Industries within and outside the country.

The Research, development and testing facilities of the Centre are located in a 200 acres plot of land at Gwalpahari village, Gurgaon (Haryana) at a distance of about 35 Kms. from the office complex of the DNES in Delhi.

8.1 Activities of Solar Energy Centre

The Current activities are moving ahead on the following fronts.

- Solar Heat Research
- System Design and Engineering
- Solar Refrigeration and Air Conditioning
- Testing and Standardization
- Materials Research Activities
- Solar Thermal Power Generation
- Solar Passive Architecture and Green House Technology

8.2 International Cooperation

The UNDP is sponsoring a project at Solar Energy Centre for setting up laboratories for Solar thermal research and testing, augmenting facilities of library, promoting transfer of technology and manpower training.

There is also a proposal to take up a joint project under technical collaboration with Germany to set up indoor test facilities for Solar energy devices and systems for further

developmental work on test standards. Discussions have also been initiated with Germany for possibilty of their funding the proposed 30 MW Solar thermal power project.

9.0 Solar Photovoltaic System

The concept of producing electricity directly from sunlight without the intermediate transformation to heat and mechanical energy is based on the " photovoltaic " effect. It has a great potential in India where there is plenty of sun and a great need for electrical energy for decentrailsed applications.These systems are particularly suited for various rural applications as they provide on-site generation of electricity. Various photovoltaic systems include-water pumpsets for micro-irrigation and drinking water supply, radio beacons for ship navigation at ports, community radio and television, cathodic protection of oil pipelines, weather monitoring, railway signalling equipment, battery charging etc.

It is estimated that at a cost of about Rupees forty per peak watt, solar photovoltaic water pumping systems would become cost effective in comparision to the present day diesel pumpsets. Though initial costs are considered high compared to other systems based on conventional energy sources, they are competitive at current prices in certain remote areas which are not served by electric grids, where it is difficult to transport conventional fuels, and where power in small capacities is required.

The scope for utilization of these devices will increase with reduction in prices through technology development and increased production. India is one of the few countries in the world to

have developed productive capability based on indigenous technique.

The photovoltaic devices are portable, require no fuel, offer a pollution free source of power, they are easy to operate, maintenence free, have long effective life and are extremely reliable. These features make photovoltaic systems most suitable for installation in remote and isolated areas, forest and hilly areas and desert locations.

9.1 Research and Development

The main objectives of the research programme have been the development of low cost solar cells, improvement in efficiency, reliability and life of PV modules and the development of PV systems for various applications. Research on various aspects of photovoltaic technology such as silicon material, thin film photovoltaic devices, other photovoltaic devices and photovoltaic systems is funded by the Department of Non - Conventional Enerrgy Sources.

* The Department has supported two power plant projects to understand the design, integration and evaluation of SPV systems.
* A 20 KWp SPV power plant project at Motilal Nehru Sports School at Rai, Haryana, was completed in November 1989.
* Another project for installation and evaluation of a 25 KWp SPV power plant, to meet thier energy requirements at Forest Lodge, Lulung, Orissa is undertaken by OREDA.
* A project for testing and evaluation of SPV refrigerators, procured under DANIDA assistance, began at IISc., Bangalore.

* A 10 ton solar refrigeration system for storage of fish by the Karnataka Fisheries Development Corporation was commissioned at Mangalore.
* A project on Solar Photovoltaic Technology Assessment is being supported at the Tata Energy Research Institute , New Delhi.

9.2 Demonstration and Field Evaluation

The Department has been implementing a photovoltaic demonstration programme for the deployment of indegenously manufactured SPV systems for demonstration, field evaluation, training, field experience, information and awarness. The programme is intended to further help improvement in quality, reliability and the overall performance and cost effectiveness of SPV systems.

9.3 Street Lighting Systems

During 1989-90 2150 street lighting systems were supplied to various State Electricity Boards and various Renewable Energy Development Agencies for installation during April-December 1989. On a cumulative basis, about 6628 villages and hamlets have benefitted by the installation of these systems.

9.4 Domestic/Community Lighting/TV Systems

Lighting of Panchayat ghars, community centres, primary health centres, night schools has continued under the demonstration programme. During April-December 1989, 245 community lighting/TV systems and 94 domestic lighting units have been provided to the villages.

9.5 Water Pumping Systems

In 1989-90, 48 water pumping systems have been supplied, raising

the total number to 1150 systems. These systems are suitable for total head upto 7-8 meters and can lift about 20,000 litres of water each day using 360 Wp PV array. Development and use of pumps to lift water from 10-20 meter depth is also being promoted.

9.6 Small Power Plants

Small decentralised photovoltaic power plants of 1-5 KWp capacity have been installed at several villages. These power plants are designed to meet the load of street lighting, domestic lighting, communtiy centre lights,community TV, telecommunication and water for drinking and irrigation purposes etc. Out of 49 small power plants sanctioned 30 have already been installed and 19 are under installation to meet the energy requirements in the remote and tribal areas.

9.7 Telecommunication Systems

Photovoltaic systems are becoming more and more viable for remote area telecommunication applications. Some of the systems powered by photovoltaics are

- Telephone Exchange, microwave repeater stations, satellite ground stations
- TV transmitters
- Television sets to receive signals directly from satellite
- Two way radios

Photvoltaic power rural telephone exchanges have been set up in Karnataka and Orissa. Microwave repeater stations are also being powered by photovoltaics in Madhya Pradesh, Rajasthan, Karnataka etc. One system of 1.6 KWp capacity has been installed recently in Anta village, Kota, Rajasthan.

9.8 Other Applications

Other applications include battery charging, railway signalling, panel inter-locking, cathodic protection of oil and gas pipelines, systems for off-shore oil platforms, weather monitoring and data collection systems etc.

The achievements of the Photovoltaic demonstration programme in 1989-90 is shown in Table 2.

TABLE 2

No.	Application	Unit	Target 1989-90	Achievements upto Dec. 31 ,1989
1.	Water Pumping	Nos.	100	48
2.	Street Lighting	Nos.	3000	2150
3.	Domestic Lighting	Nos.	100	94
4.	Community TV/ Lighting	Nos.	100	245
5.	Power plants & other applications	KWp	100	70

9.9 Industrial Production

The DNES functions as the administrative minstry for industrial registration, licencing, foreign collaborations and imports etc. in the area of photovoltaics. In addition to BHEL, CEL and REIL, Udhaya Semi-conductor Pvt. Ltd. and Indian Metal & Carbides Ltd. have started production of solar cells and modules. Suryavonics, an export oriented undertaking for the production of amorphous silicon modules also started functioning. The production performance in the 1989-90 is shown in Table 3.

TABLE 3

Product	Manufacturer	Production	Unit
Solar Cells	BHEL	134	KWp
	CEL	240	KWp
	Udhaya	6	KWp
PV Modules	BHEL	134	KWp
	CEL	340	KWp
	REIL	110	KWp
	Udhaya	6	KWp
Poly Silicon	Metkem	6.24	Tonne
Single Crystal Ingots	Metkem	3492	Kg
	Siltronics	245	Kg
Single Crystal Wafers (100 mm Dia)	Metkem	1,94,651	No.
	Siltronics	62,000	No.

9.10 International Cooperation

Under the UNDP assisted project on development of amorphous silicon solar cells at Indian Association for Cultivation of Science, Calcutta, multi chamber CVD equipment has been received and installed at the Institute. Testing of two solar PV refrigerators procured under DANIDA assistance programme is going on at IISc., Bangalore.

10.0 Conclusion

Of all Renewable Sources of Energy, Solar Energy offers an immense potential in the long term. It is the first to have been used by man.

Solar systems are best suited for remote areas where it is not possible to take transmission lines without escalating costs. The emphasis on solar energy applications can be said to meet the social and economic needs of society. Cost consideration should be looked at in terms of social and economic benefits. Community facilities of street lighting, drinking water and cooking energy can be attended to by utilizing solar energy.

As Solar Energy offers a vast potential the Department of Non-Conventional Energy Sources has set up an R & D facility at its Solar Energy Centre near Delhi.

Interaction between Industry and R & D institutions should be intensive which will help in the identification of technologies in different sites of modifications required for adaptations.

APPENDIX I

Cost Sharing Scheme for Installation of Low Grade Solar Thermal Systems And Devices +

No.	Category of Users	Percentage of Central Govt. Sharing		
		87-88	88-89	89-90
1.	Private Sector	33 1/3	30	30
2.	Govt. Public Sector	50	40	30
3.	State Govt. Buildings, Coop. Soc, Central Govt. Buildings, Govt. Aided/funded Autonomous Bodies, Educ. Inst., IIT's, Unis., Schools, Anganwadis, Charitable & Other religious bodies.	75	60	50
4.	Domestic Solar Water Heaters *	50	40	40
5.	Solar Cookers **	33 1/3	33 1/3	33 1/3
6.	Community Solar Cookers ***	_	33 1/3	33 1/3

* Subject to a maximum of Rs. 3,000/- per DSWHS

** Subject to a maximum of Rs. 150/- per Solar Cooker

*** Subject to a maximum of Rs. 1,050/- per Solar Cooker

\+ Annual Report 1989-90, DNES.

APPENDIX II

Statewise List of Solar Thermal Systems Installed in India (Upto 31.12.1989) +

No.	State/Organisation	Solar Water Heater	Capacity (lpd)	Area (M^2)	Domestic SWH No.	Domestic SWH Capacity	Area (M^2)	Air Heaters Nos.	STK Nos.	Stills Nos.
1.	Andhra Pradesh	65	2,79,000	4310	58	5800	116	1	4	67
2.	Assam	46	17,000	300	-	-	-	3	-	-
3.	Arunachal Pradesh	43	11,900	340	-	-	-	1	1	20
4.	Bihar	23	23,200	464	-	-	-	-	-	-
5.	Chandigarh	24	21,000	420	-	-	-	-	-	-
6.	Delhi	130	4,25,000	8500	428	42800	856	1	2	1604
7.	Goa, Daman, Diu	8	8,500	170	-	-	-	-	-	-
8.	Gujarat	791	13,46,700	25301	2599	3,87050	7706	8	11	4318
9.	Haryana	74	1,87,000	3620	30	3000	60	-	1	120
10.	Himachal Pradesh	36	76,400	1620	19	1900	30	-	2	-
11.	Jammu & Kashmir	31	43,400	862	6	600	12	-	-	70
12.	Karnataka	72	2,32,400	4882	223	22300	446	1	2	-
13.	Kerala	25	36,200	742	3	300	6	1	-	10
14.	Meghalaya	10	12,700	356	-	-	-	-	-	-
15.	Maharashtra	46	1,24,800	2496	-	-	-	-	-	145
16.	Madhya Pradesh	137	6,63,050	16096	12	1350	27	2	1	300
17.	Orissa	57	74,650	1493	-	-	-	2	-	278
18.	Punjab	130	1,87,700	3778	50	5000	100	1	2	122
19.	Rajasthan	178	86,050	1701	20	2000	40	-	-	-
20.	Sikkim	1	2,000	-	2	300	6	-	-	-
21.	Tamil Nadu	151	4,78,325	10213	681	68100	1362	1	-	-
22.	Tripura	4	4,000	100	-	-	-	-	-	10
23.	Dadra & Nagar Haveli	2	3,000	42	-	-	-	-	-	-
24.	Uttar Pradesh	294	5,73,350	11567	42	4200	84	13	12	196
25.	West Bengal	75	19,600	392	1	100	2	1	1	75
26.	Pondicherry	16	13,850	277	-	-	-	-	-	20
27.	C.P.W.D.	5	27,000	540	-	-	-	-	-	-
28.	Railways	16	17,450	349	-	-	-	-	-	328
Total		2490	49,95,125	1,00931	4174	5,44800	10857	36	39	7683

+ Annual Report, 1989-90, DNES.

APPENDIX III

Ongoing Research & Development Projects for Solar Thermal Energy

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1. Design Development and testing of thermosiphon Domestic hot water system without reverse flow, IIT, Delhi.

2. Extraction of Ethyl alcohol from Fermented Sorghum Juice by Solar Energy Phase-II, N.A.R.I., Phaltan (Maharashtra).

3. Evaluation of seasonal Thermal Storage in aquifer for heating and cooling, Punjab University, Chandigarh.

4. Design, Development and Evaluation of Solar Kier, IIT, Delhi.

5. Development of Solar Dehydration System for field trials for dehydration of grapes to produce Resin, University of Poona, Pune.

6. Field Demonstration of Solar Thermal Pump, BHEL, Hyderabad.

7. Design of Solar Passive Houses in Ladakh, IIT, Delhi.

8. Utilization of Solar Energy for drying of agricultural and food materials in improved solar dryer, Jadavpur University; Calcutta.

9. Design, Development of Instruments and Devices for Passive Solar Architecture Applications, IIT, Delhi.

10. Indo-German Project on the theoretical and experimental investigation of Solar Passive Buildings, IIT, Delhi.

11. Design, Fabrication, Transportation and supply of experimental solar TAP walls/Direct Gain Sidings for 30 huts in Himachal Pradesh and Uttar Pradesh , Sectors of Indo-Tibetan Border Police, Solar Energy Centre, Delhi.

12. Development of Solar Thermal pump with evacuated tube collector for installation in the premises of Solar Energy Centre, BHEL, Hyderabad.

13. Design, analysis and studies on Solar Collectors with Heat Transfer fluids for their applications in Industrial Heat Processing, Refrigeration and Air Conditioning, IIT, Delhi.

Annual Report, 1988-89. DNES, Government of India.

14. Monitoring and performance study of Solar Thermal Power Generation plant,Sardar Patel Renewable Energy Institute, Vallabh Vidyanagar.

15. Setting up Solar powered milk chilling centre at Raebarelly, NEDA, Lucknow.

16. Renewable Energy system at Sericulture Research Station, Pampore, Srinagar.

17. Development of stirling engine based autonomous solar powered plant in collaboration with USSR, CMSCRI, Bhavnagar.

18. Dynamics of Solar Ponds,IISc., Bangalore.

19. Development of panels of various designs using evacuated collectors and setting up a demonstration system for water sterilization, IBP Co.Ltd., Sewri, (East), Bombay.

20. 50 KW power Plant at Gwal Pahari (Gurgaon), SEC, New Delhi.

21. Installation of Solar Water Heating Systems for 88 Quarters of Indo-Tibetan Border Police in Leh, Srinagar, C.P.W.D.,New Delhi.

22. Solar Pond, GEDA, Baroda.

23. Development Optimization and study of Solar Thermal Systems using linear Solar concentrator, IIT, Delhi.

24. Stirling engine, Solar Energy Centre, New Delhi.

25. Design, Development fabrication and testing of vacuum Tube Collectors-Phase II, School of Energy Studies and Material Sciences, Pune .

26. Medium temperature high efficiency tracking solar energy collectors for rural and industrial application, IISc., Bangalore.

27. Effect of interstial pressure and temperature on thermal condition through porous and dispersed system and its application to solar thermal storage, University of Rajasthan, Jaipur.

28. Augmentation of Network of Radiation stations in India, Metereology Department, New Delhi.

29. Design and development of continuos absorption refrigeration and air conditioning systems, IISc., Bangalore.

30. Chemical storage of solar radiation, Delhi University, Delhi.

31. 3-Ton Solar Powered Refrigeration Plant for sub zero operating temperature Phase II, Sardar Patel Renewable Energy Research Institute, Vallabh Vidyanagar.

32. Development of Solar Refrigerator using zeolite for rural areas, Sardar Patel Renewable Energy Research Institute, Vallabh Vidyanagar.

33. Design Construction and evaluation of solar passive house Phase II, IIT, Delhi.

APPENDIX IV

List of R & D Projects supported by DNES during 1988-89 *

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1. Development of Amorphous Silicon thin films solar cells, I.A.C.S., Calcutta.

2. Research, Development and Production of Amorphous Silicon Solar cells,University of Poona, Pune.

3. Development of Amorphous Silicon Solar Cells, IIT, Delhi.

4. Development of techniques for the production, operation and storage of Silanes from rice husk for preparing a-Si, IIT, Kharagpur.

5. Production of Silane for Amorphous silicon & polysilicon applications, IISc., Bangalore.

6. Amorphous Silicon Solar Cells - Development & Evaluation studies, IIT, Madras.

7. Investigation of Hydrogenated Amorphous Silicon Films, N.P.L., Delhi.

8. Polycrystalline Silicon from rice husk, IIT, Kharagpur.

9. 5 KW Solar PV power system demonstration cum utility project, Engineering Staff College, Hyderabad.

10. Feasibility studies on the development of an organic dye solar cell, IIT, Delhi.

11. Photoelectrochemical Energy Conversion, IIT, Delhi.

12. Energy Conversion in Photelectrochemical systems, IIT, Delhi.

13. Development and Demonstration of concentrator photovoltaic systems for specific stand alone rural appplications, Kalyani University, Kalyani.

14. Development of Thermoelectric Generator for Solar (and other) energy conversion, IIT, Kharagpur.

15. Indium Tin Oxide based interfacial layer Heterojunction solar cells Phase-II, IIT, Delhi.

16. Studies on InP based heterojunction solar cells InP/ITO and Inp/cds, I.A.C.S., Calcutta.

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* Annual Report, 1988-89, DNES, Government of India.

17. Study of Ternary Chalcopyrite Semiconducting films as photovoltaically active material, University of Rajasthan, Jaipur.

18. Development and demonstration of solar energy concentator for photovoltaic panel, IIT, Delhi.

19. Development of the film CdTe heterojunction solar cells, Sri Venkateshwara University, Tirupati.

20. Solar Cells Technology Assessment, TERI, New Delhi.

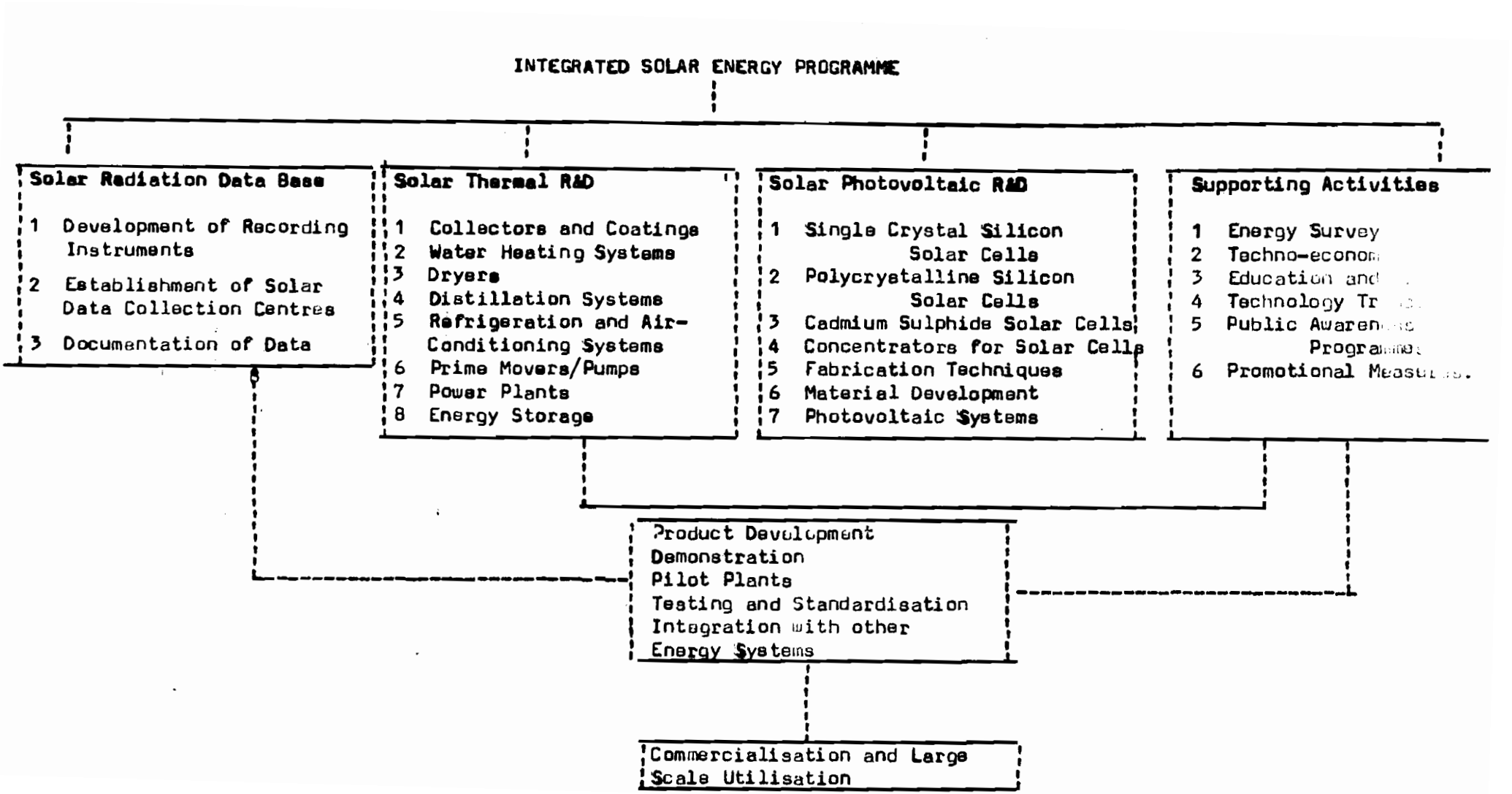
21. Evaluation of individually managed solar PV water pumping systems in the states of Andhra Pradesh, Orissa, Tamil Nadu, Administrative Staff College, Hyderabad.

22. Project on study of high efficiency deep water pumps for application in solar PV systems, REIL, Jaipur.

23. Proposal for research on decentralised energy options in Rural Sector, TERI, New Delhi.

24. Evaluation of individually managed solar PV systems in the states of Bihar, U.P. & West Bengal, N.P.C., New Delhi.

25. Reduction in Energy consumption and cost of production of silicon for photovoltaic applications, M/s. Metkem Silicon Ltd., Madras.


INTEGRATED SOLAR ENERGY PROGRAMME
Solar Radiation Data Base
1 Development of Recording Instruments
2 Establishment of Solar Data Collection Centres
3 Documentation of Data
Solar Thermal R&D
1 Collectors and Coatings
2 Water Heating Systems
3 Dryers
4 Distillation Systems
5 Refrigeration and Air-Conditioning Systems
6 Prime Movers/Pumps
7 Power Plants
8 Energy Storage
Solar Photovoltaic R&D
1 Single Crystal Silicon Solar Cells
2 Polycrystalline Silicon Solar Cells
3 Cadmium Sulphide Solar Cells
4 Concentrators for Solar Cells
5 Fabrication Techniques
6 Material Development
7 Photovoltaic Systems
Supporting Activities
1 Energy Survey
2 Techno-econom
3 Education and
4 Technology Tr
5 Public Awaren
Progra
6 Promotional Measu
Product Development
Demonstration
Pilot Plants
Testing and Standardisation
Integration with other Energy Systems
Commercialisation and Large Scale Utilisation