SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE

ANNUAL REPORT | 2018-19

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Highlights of the Year

Renewable energy in India driven by policy push and falling prices, is witnessing many success stories. But, at the same time to achieve the climate change targets by 2030 through alternative clean energy investments, as per International Finance Corporation, around 450 billion USD is required. Seeing large market potential in India, several global renewable energy companies and start ups in India have therefore come up, making significant progress in recent years. But, on the other hand, raising cash for big-scale implementations is now warying developers due to the concerns on the project viability in low-tariff regime particularly for solar and wind energy sectors. In addition to this, India has attracted only around 3% of the global investment in renewables this year. Large numbers of renewable energy-based implementation tenders are either cancelled or got delayed due to issues faced by developers.

Despite of all these hurdles, country is running its ambitious flagship programme with plans to achieve 175 GW of renewables by 2022 and 500 GW by 2030. To meet the targets, renewable energy and energy storage systems is now taking the lead role in country's energy transformation. International Solar Alliance launched by India in association with France, is putting their much efforts in solar energy regime.

For Indian perspective, to address the climate change and renewable energy targets, paved by Indian government, renewable energy will keep playing center-stage role. In order to improve further on developing good and reliable renewable energy-based technologies, Government through different focussed research and development programme is supporting the efforts put up by various institutes/organizations across the country.

SPRERI in-line with Government of India's broad agenda continues its research and development in renewable energy technologies. Under bio-chemical conversion division, to address stubble burning issues of Punjab and Haryana, team is developing technology for converting crop-residues to gaseous bio-fuel in a continuous mode. During the year, team has also put focus on treating other solid waste/effluents i.e. kitchen-waste, dairy effluent and waste from potato-based industries etc. and successfully demonstrated by implementing filed level plants in institutions/industries to meet their thermal requirements. SPRERI also organized a One-day brain-storming session on "Recent advances in production of 2G bio-fuel in India" on 10th July 2018 at Vallabh Vidyanagar, Gujarat with financial support from GSBTM, Gandhinagar.

Under thermo-chemical conversion division, a 25 kg/h loose biomass-based fluidized bed gasification system developed in-house is put under rigorous testing. Various agricultural feed stocks are being tested in the system mainly to meet the thermal requirements at Poha making industries in Gujarat. In addition, the double-pot natural-draft improved biomass cookstove with chimney is developed to cater the needs of rural/tribal populace.

Under solar energy division, 30 number 50-kg/day capacity PV-integrated low tunnel solar dryers were installed at Cambodia through a project supported by Ministry of Cambodia. Other research programs on Efficiency enhancement of solar thermal collectors using nanofluids

and Development of solar air heaters integrated with PV for combined thermal and electrical applications are still in progress.

MNRE supported, BIS approved and NABL accredited Regional Test Center at SPRERI completed testing of 9 solar thermal devices during the year as per BIS/MNRE approved procedure. The devices tested included 6 flat plate collector-based water heaters, 1 evacuated tube collectors-based solar water heaters and 2 solar box cookers.

SPRERI has extended their resource personnel in various training programmes throughout the year. The technology transfer (extension) division, during the year has implemented 1000 number SPRERI developed improved biomass cookstoves in the tribal areas of Jharkhand under the project supported by Jharkhand Tribal Development Society.

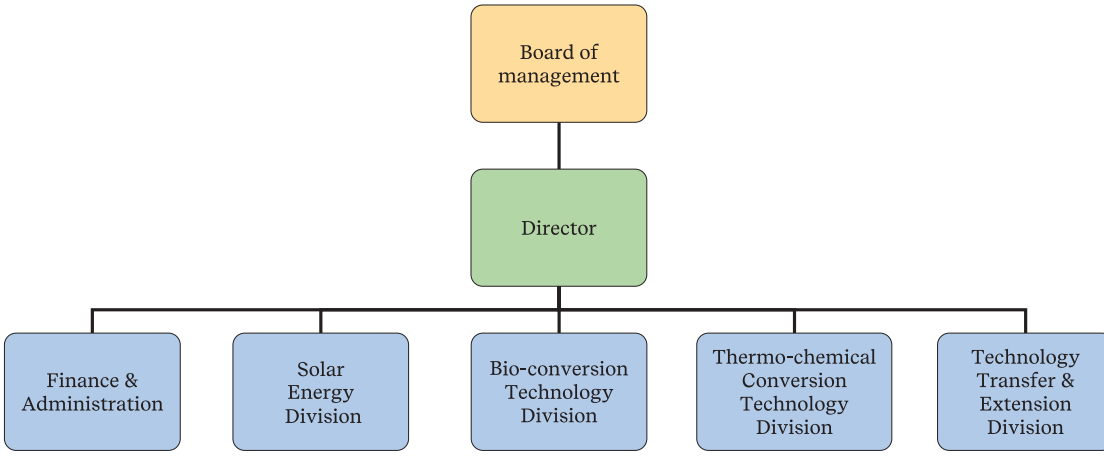
The annual event "Open House" was organized at SPRERI on February 15-16, 2019. More than 2800 persons, primarily under-graduate and post-graduate students and faculty of engineering, management and science colleges from all over Gujarat, participated in the "Open House".

SPRERI towards a biennial "Hari Om Ashram Prerit Lecture" on renewable energy has invited Shri Y B Ramakrishna, Member-Working group on bio-fuels, Ministry of Petroleum & Natural gas on 29th March 2019 to deliver a lecture on "Biomass based liquid & gaseous fuels – The new policy framework and sustainable initiatives in India towards creating bio-economy".

The Organization & Structure

Sardar Patel Renewable Energy Research Institute (SPRERI), established in 1979, is an autonomous and not-for-profit organization managed by a Board comprising leading technologists, scientists, industrialists and representatives of Central and State Governments. It is recognized by the Department of Scientific and Industrial Research, GoI, as a Scientific and Industrial Research Organization. It is also approved as a Research Association for the purpose of clause (ii) of sub-section (1) of section 35 of IT Act, 1961. It generates most of its operating funds through projects given to it on merit by government and non-government organizations. SPRERI's service activities like consultancy, technology evaluation, testing and training supplement the project funds to make it self-supporting. It is a renowned renewable energy (RE) research institution and is recognized for post graduate research by many others academic institutions and universities.

Solar energy, bio-conversion and thermo-chemical conversion of biomass are the three major fields of specialization at SPRERI. Many renewable energy devices and systems developed at SPRERI are now manufactured by selected industries and supplied to end users. In addition, the promotion of renewable energy technologies is pursued through field evaluation and demonstrations, training and entrepreneurship development, awareness programmes and integrated development of selected tribal villages. SPRERI organizes "Open House" for two days every year to create awareness about RE technologies, among citizens, particularly the youth. Under graduate and post graduate students from all over the state visit SPRERI during Open House.



Vision & Mission

VISION

- SPRERI will be an organization that will develop environment friendly Renewable Energy Technologies that are efficient and economically viable for society

MISSION

- Be a leader in developing technologies itself and through collaboration that can be deployed in India and developing countries in the renewable energy space
- Provide training, guidance and overall knowledge management in the renewable energy space
- Source funding from Government and Organizations for projects of national interest
- Develop a Revenue Stream vide the technologies that have been developed at SPRERI and its extension services

Board of Management

Dr. Amrita Patel	Trustee, Charutar Arogya Mandal, Karamsad
Prof. B.S. Pathak	Ex-Director, SPRERI and Energy Consultant KC-5, Kavi Nagar, Ghaziabad
Shri P.C. Amin	Director, Elecon Group of Companies M/s Elecon Engineering Co. Ltd., Vallabh Vidyanagar
Dr. Kanchan K. Singh	Assistant Director General (Engg) Indian Council of Agricultural Research, New Delhi
Shri Deepak Joshi	Head, Electronics & Controls Systems Division M/s Jyoti Limited, Vadodara
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Dr. Datta Madamwar	UGC-BSR Faculty Fellow, Post-Graduate Department of Biosciences, S.P. University, Vallabh Vidyanagar
Mr. Sydney V. Lobo	Chief – Business Collaboration The Tata Power Company Limited, Mumbai
Dr. Gaurav Mishra	Director, SPRERI, Vallabh Vidyanagar (Member-Secretary)

1.1 Solar air heaters integrated with PV for combined thermal and electrical applications

The performance of solar collectors with and without PV integrated glass covers was tested. Air flow was maintained and controlled in PV integrated collectors to gain heat. In the thermal collector, the air flow was maintained between absorber and inner back plate. With the introduction of PV cells, the average values of the transmittances (measured as per BIS standards) for covers of collector without and with PV integrated glass were found to be 87.5% and 4.54%, respectively. Solar thermal conversion efficiencies of both types of collectors were also determined by performing outdoor experiments in clear weather conditions. The experiments were conducted under natural and forced convection modes, with avg. air velocities of 1 m s^{-1} and 8 m s^{-1}, respectively. Solar electrical conversion efficiencies of both types of collectors were measured using PV analyzer and comparative performance under natural and forced convection modes was made which is given in Table 1. The thermal efficiencies, i.e. with and without PV cells was found to be increased 4-fold in force convection to natural convection mode, whereas, the electrical performance of the PV integrated collector was found to be increased by 7% under force convection mode

Table 1: Comparative performance of solar air heaters

Sr. No.	Mode of evaluation	Avg. thermal efficiency (%)		Avg. electrical efficiency for PV integrated collector (%)
		Glass without PV	*Glass integrated with PV*	
1	Natural convection @ 1.0 m s^{-1}	6.87	5.29	8.70
2	Forced convection @ 8.0 m s^{-1}	28.77	19.82	9.30

Further, three identical collectors from each category were arranged in series as shown in Fig. 1 to assess and compare the performance in both the cases at different air flow rates. P1 to P3 are PV based thermal collectors and Th1 to Th3 are plain glass thermal collectors. Both the arrays were connected to a single common blower with an arrangement of adjusting air flow rate. Air temperature at inlet and outlet of both the collector arrays were measured and logged. The tests were performed at three different flow rates (i.e. 65.67 m^3 h^{-1}, 98.51 m^3 h^{-1} and 109.45 m^3 h^{-1}). At the same time, electrical performance of each PV + thermal (PVT) collector in the PVT array was monitored using PV analyzer. Average air temperature at inlet and outlet of both the collector arrays as well as the electrical performance of the PV panels were measured and given in Tables 2-3.

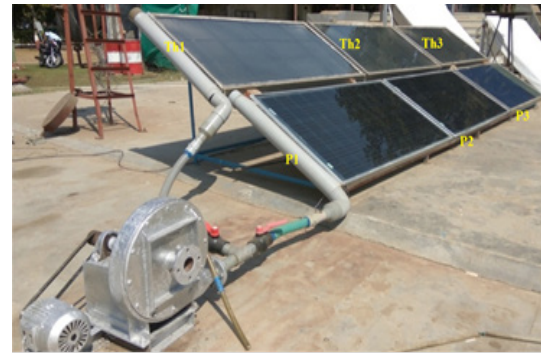

Fig. 1: Solar thermal and PVT collector test set-up

Table 2: Average temperatures at outlet of collectors for different air flow rates

Flow rate (m^3 h^{-1})	Inlet (°C)	Thermal (°C)	PVT (°C)
65.67	26.06	57.43	46.00
98.51	30.93	63.13	57.58
109.45	34.13	64.78	57.96

The power output from each PV panel decreased on increasing panel surface temperature and flow rates. The power output seems to be decreased at 109.45 $m^3 h^{-1}$ flow rate, which is unexpected but could be a result of higher inlet air temperature.

Table 3: Average percent output of rated electric power of PVTs at different air flow rates

Flow rate ($m^3 h^{-1}$)	P1	P2	P3
65.67	46.92	47.06	48.70
98.51	49.23	48.52	49.13
109.45	49.20	47.60	48.23

1.2 Efficiency enhancement of solar thermal collectors using nano-fluids

Aluminium based nano-materials of 50-100 nm size of high purity was procured from Sigma Aldrich. Nano-fluid was prepared using the procured nano-materials in volume fraction (ϕ) of 0.01, 0.015, 0.02 (Fig. 2) and water as base fluid. Thermo-physical properties of the prepared nano-fluid with volume fraction (ϕ) of 0.01 were calculated considering the properties of nano-material and base fluid and are given in Table 4.

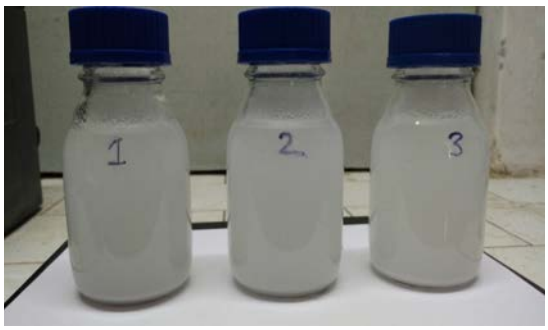

Fig. 2: Nano-fluid concentrations i.e. 1) ϕ = 0.01, 2) ϕ = 0.015, 3) ϕ = 0.02

Further, thermal performance of a direct absorption solar collector, gross area of 0.65 m^2, using prepared nano-fluid as direct solar absorbing material as well as heat transfer fluid was tested under outdoor natural environment. The line diagram of the experimental set-up is shown in Fig. 3. Experiments were performed at a flow rate of 0.5 lpm.

Table 4: Thermo-physical properties of the nano-material, base fluid and nano-fluid

	Nano-particles	Water	Nano-fluid (ϕ = 0.01)
Density ($kg^{-1}m^3$)	3880	998	1026.8
Thermal conductivity ($W\ m^{-1}\ K^{-1}$)	36	0.608	1.009
Specific heat capacity ($kJ\ kg^{-1}\ K^{-1}$)	0.773	4.187	4.058
Viscosity (mPa.S)	-	0.89	0.965

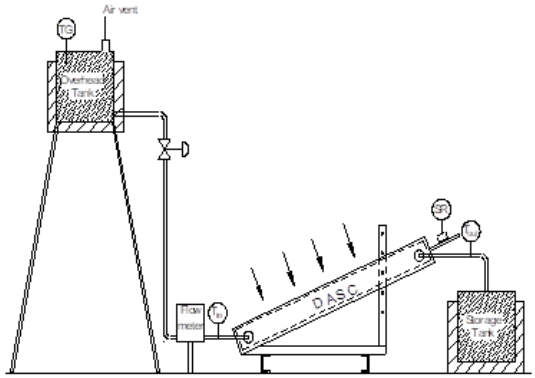

Fig. 3: Set-up and monitored parameters during the testing period

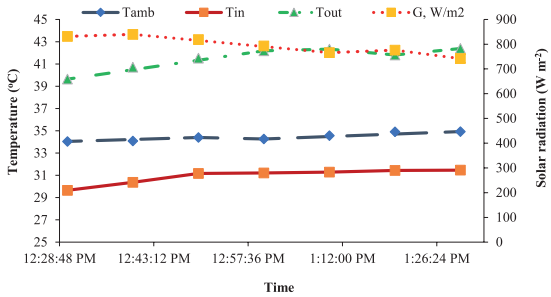

Fig. 4: Experimental results of thermal performance of direct absorption solar collector

The temperature at the outlet of collector was observed close to 43°C during the testing period between 12:30 PM and 1:30 PM (Fig. 4). Further, the efficiency of the system using the fluids with different concentration in the solar collectors is under progress.

1.3 Design, development and performance evaluation of a downscaled PV integrated low tunnel dryer

A single module low tunnel solar dryer having flat plate collector for air heating has been developed by downscaling the earlier three module SPRERITECH PV integrated low tunnel solar dryer. The system re-sizing was done to address the issues of high cost (approximately Rs. 1.00 lakh) and to counter the limitations of installation site particularly at the building terrace. A smaller system with 60% less cost was found to be arranged easily.

Fig. 5: Single module PV integrated low tunnel dryer

The newly designed single module dryer consists of two doors (one at each sides) and two small capacity (0.24 V, 0.2 A) DC fans to blow air in the drying chamber. The fabricated single module system is shown in Fig. 5. Preliminary no load testing of the system was done. The no load testing of the solar dryer was carried out for summer and winter seasons. The maximum values of the outlet air temperature were observed close to 50°C for summer and 40°C for winter days at 300 m^3 h^{-1} air flow rate. To achieve further higher temperatures i.e. 50°C and above, evacuated vacuum tubes with expected better solar radiation absorptivity and very low emissivity as compared to a black powder coated flat metal surface were considered.

An evacuated tube based solar dryer (ETCD) prototype has been developed (Fig. 6). A fan is used at the exhaust to draw hot air through the system. For air heating, preliminary results were generated at no load condition and were also compared with earlier developed single module low tunnel dryer (SMD) as shown in Fig. 7. The average air flow rates in SMD and ETCD were 183 and 230 m^3 h^{-1}, respectively. The maximum temperature, at the outlet, achieved in the ETCD and SMD was 62.5 and 39.9°C, respectively. Further testing of the system is in progress.

Fig. 6: ETC tube based dryer prototype

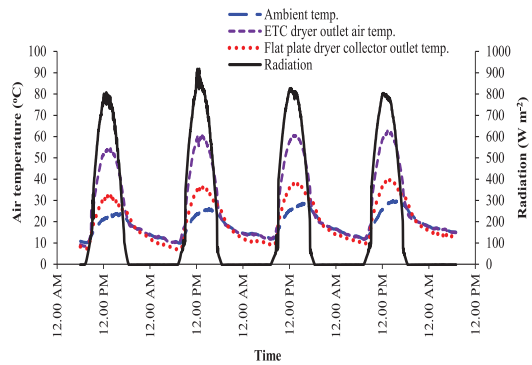

Fig. 7: Temperature profile of ETC and flat plate dryer prototypes for air heating

1.4 Efficiency enhancement of Scheffler dish concentrating technology

During June 2018, a Scheffler dish solar concentrating system with cavity receiver was installed at Annapurna Canteen (Hostel canteen), Shree Krishna Hospital, Karamsad (Fig. 8) for providing hot water/steam for cooking and cleaning purposes. The system was tested for heating 200 L water in cloudy

conditions and maximum temperature of water was measured as 75°C (Fig. 9). The water temperature was found sufficient for using in the dish washer. Training on system operation and maintenance was imparted to the canteen staff.

Fig. 8: Photograph of system installed at Shree Krishna Hospital (Karamsad)

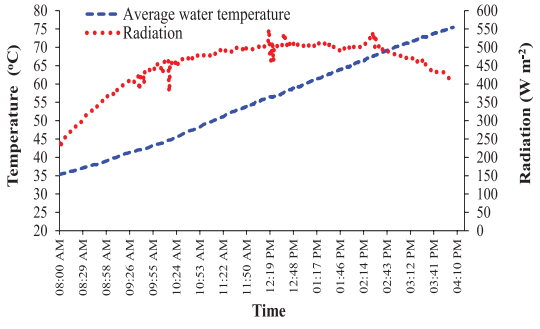

Fig. 9: Water temperature with passage of time

1.5 Regional Test Centre

The MNRE committee visited SPRERI on 24 May, 2018 and reviewed the RTC activities and was satisfied with the overall progress, and as follow up again, details were submitted in the prescribed report format on 5 June, 2018.

For updating NABL 17025:2005 to 17025:2017, Er. Asim Joshi underwent 2-days transition training during 19-20 June, 2018 at NITS, Noida. The quality manual was updated as per ISO 17025:2017 and the NABL accreditation renewal application was sent on 24 August, 2018. The NABL renewal assessment was carried out during 6-7 October, 2018. On 30 November, 2018, the NABL accreditation was granted to RTC-SPRERI for testing FPC and SBC as per IS/ISO 17025:2017 with new certificate no.: TC-8168.

Details on number of samples received for testing are mentioned below in Table 5. Test reports issued for the same are also indicated in Table 5.

Table 5: Statement of devices received and tested during the year

Devices	Received for testing (Units)	Testing completed (Units)*
Solar flat plate collectors		
· BIS	1	1
· Manufacturer	2	5
· Inter Laboratory Comparison	0	0
Solar box cooker		
· BIS	0	0
· Manufacturer	0	0
· ILC	0	2
ETC/FPC based solar water heating systems	0	1
Total	**3**	**9**

*Includes few devices which were received during the previous year

2.1 Anaerobic digestion

Conversion of crop residues to gaseous bio-fuel in a continuous mode

At SPRERI, a zero-waste approach has been attempted on utilization of solids and liquids generated during anaerobic fermentation of rice straw to bio-methane. To start with, initially the enzymatic hydrolysate was used as a sole carbon source for bio-gas generation on a continuous mode using thermophilic anaerobic hybrid reactor (AHR). The results revealed that at 2 day hydraulic retention time, 17% higher bio-gas and 27% higher methane yields were obtained as compared to the earlier SPRERI developed process which took 20 days to generate 325 L bio-gas from kg rice straw with 59% methane content. COD removal rate was 80%. Simultaneously, attempts were also made to produce eco-friendly carbon neutral pellets (4 mm size) from left over solid residue which showed thermal efficiency of around 36% in the forced-draft improved biomass cookstove when tested as per BIS standards IS13152 (Part 1): 2013. Performance details of the cookstove are given in below (Table 6). Lignin was extracted from the liquid portion (black liquor) of alkali pre-treated rice straw using precipitation method. Calorific value of produced pellets and the extracted lignin were 13.251.8± MJ kg^{-1} and 18.69±2.1 MJ kg^{-1}, respectively.

Table 6: Performance of pellets in forced-draft improved biomass cookstove (IBCS)

	Efficiency (%)	Burning rate (kg h^{-1})	Power rating (kW)	CO (g MJ_d^{-1})	TPM (mg MJ_d^{-1})
BIS limit	≥ 35	-	0-3	≤ 5	≤ 150
Forced-draft IBCS	36	1.07	1.56	2.69	70.06

Potato processing wastes

Potato processing wastes i.e. potato peels, cooked potato waste and potato wastewater were collected from a potato processing plant located near the Institute to evaluate its bio-methanation potential and to set-up a demonstration bio-gas plant in the potato processing industry. Bio-gas yields obtained were 78 and 123 L kg^{-1} of potato peels and cooked potato waste, respectively with methane content of 65%. The performance of daily fed reactors treating potato solid wastes is given in Table 7.

Table 7: Performance of anaerobic reactors treating potato solid waste

Waste	HRT (d)	Total solids (%)		TS removal (%)	Avg. bio-gas yield in L per	
		In	Out		day	g TS
Potato peels	40	10	4.12	58.8	3.9	0.49
Cooked potato	40	10	4.40	56.0	3.7	0.47

Simultaneously, potato wastewater was treated with a laboratory scale AHR with 30 L capacity using synthetic packing media with inlet COD of 15000 mg L^{-1} and different HRT's 10, 5, 2 and 1 day. It was observed that similar COD removal efficiency as well as bio-gas yield of 80% and 0.39 L g^{-1} COD_{fed}^{-1}, respectively were obtained at 2 and 1 day HRT. Performance data of AHR treating potato wastewater with polypropylene pall ring as packing media is given in Table 8. Optimization of the reactors treating solid and liquid wastes was completed and a few potato processing industries were approached to set-up a demonstration bio-methanation plant.

M/s Goodrich Cereals, Karnal, Haryana agreed to install a SPRERI designed AHR to treat 1,50,000 LPD potato wastewater for bio-gas production. The installation of the bio-methanation plant is in progress.

Table 8: Performance of anaerobic hybrid reactors treating potato wastewater

Media	HRT (d)	Effluent fed ($L\ d^{-1}$)	Avg. COD ($mg\ L^{-1}$)		COD removal efficiency (%)	Avg. bio-gas yield in L per	
			In	Out		Day	g COD_{fed}
Pall rings	10	3	15000	1940	87.1	24.3	0.54
Pall rings	5	6	15000	2200	85.3	45.8	0.51
	2	16	15000	2970	80.2	94.3	0.39
	1	32	15000	3050	79.6	191.6	0.39

Dairy effluent scum

The main aim of the project is to reduce the HRT of 40 days as commonly observed in conventional bio-methanation systems by introducing a pre-hydrolysis step to enhance the rate of bio-methanation process. Based on the results obtained in batch reactors and laboratory scale daily fed reactors, thermal pre-treatment (121°C for 15 min) has been optimized for treatment of dairy effluent scum to improve the hydrolysis process of anaerobic digestion in a continuous stirred tank reactor (CSTR). Modification of an existing 240 L reactor to CSTR by fixing a stirrer with motor and speed regulator for homogenous mixing and enhancing the digestibility of substrate has been carried out.

Bio-methanation studies have been carried out using pre-treated (121°C for 15 min) dairy effluent scum as the substrate in CSTR for 10% total solids concentration (TSC) and HRT at 40 days. The performance of the CSTR is given in the following Table 9 and compared with respect to conventional bio-methanation system.

Table 9: Performance of the CSTR with conventional bio-methanation for treatment of dairy effluent scum

Parameter	Conventional bio-methanation	CSTR
Pre-treatment conditions	No pre-treatment	No pre-treatment
HRT (d)	40	40
Effective volume of the reactor (L)	900	240
Dairy scum fed • wet mass ($kg\ d^{-1}$) • dry mass ($kg\ d^{-1}$)	 22.5 2.25	 6 0.6
TS fed (%)	10	10
Avg. bio-gas production ($L\ d^{-1}$)	1040	338
Bio-gas yield ($L\ kg^{-1}\ TS_{fed}^{-1}$)	462	563
% increase in bio-gas yield	-	21.8
Methane (%)	70	68
Carbon dioxide (%)	29	26
Hydrogen sulphide (ppm)	30	30

Pellets from banana stem

The main aim of the project is to co-pelletize the dairy industrial waste with agro-residual crops with different blends to test in cook stove/boiler for domestic/industrial uses for better combustion. Initially, pellets were produced from dairy scum waste of 4 mm size and tested for burning rate. It was found that a suitable binder is required for good quality pellet production. Simultaneously, agro-residual crop-fresh banana stem was pre-sized into 5 mm size and dried in the open sun. The dried banana stem was ground into powder using a grinder of 3 mm mesh. The powdered banana stem was then used to produce pellets of three different sizes of 4, 6 and 8 mm using a commercial pellet making machine at SPRERI and tested for thermal efficiency using a commercial forced draft domestic size cook stove. The thermal efficiency was found to be

maximum of 36.12% with 8 mm banana stem pellets without binder. Further experiments are in progress to co-pelletize dairy industrial waste with different blends of agro-residual crops like banana stem and rice straw for better combustion properties to use it in boilers for industrial use.

SPRERI cellulosic ethanol technology

Pilot-scale pre-treatment of ligno-cellulosic biomass using green solvents

Earlier, pilot-scale pre-treatment of rice straw using SPRERI developed green solvents has been reported. In line with an integrated bio-refinery approach, maximum valorization of the ligno-cellulosic biomass is preferred by extraction and recovery of value added products. Lignin is one such high-value product that is obtained from ligno-cellulosic biomass. The study demonstrated applicability and potential of green solvents for efficient solubilization and recovery of high purity lignin and xylan from ligno-cellulosic biomass. Moreover, the green solvent was effectively recovered and reused at least 3-times for consecutive biomass pre-treatment without losing its efficiency.

Co-production of liquid/gaseous bio-fuel from pre-treated ligno-cellulosic biomass

The solid residue of corncob obtained after dilute acid pre-treatment of HNO_3 was further delignified with different concentrations of NaOH i.e. 0.5, 1.0 and 1.5 % (w/v), respectively at 121°C for 15 min. The liquid fraction (black liquor) obtained during delignification was used to extract lignin. The black liquor was precipitated to obtain a final pH value 3. After complete precipitation, the content of each flask was filtered through vacuum filtration unit. The lignin was dried at 25°C for 48 h. The calorific value of extracted lignin was 21.05±2.9 MJ kg^{-1}. The major lignin derived compounds identified were 2,3-dihydrobenzofuran, 4-methoxy phenol (H-type), 2-methoxy-4-vinylphenol (G-type) and acetosyringone (S-type). These are the derivative compounds of p-hydroxy-phenyl-propane, guaiacyl-propane and syringyl-propane, respectively. The aldehyde compound (3,4,5 tri-methoxy benzaldehyde) could be of interest to the aroma and perfume industries.

Refinement of in-house cellulosic ethanol technology

During the year, cellulase producing microorganisms were isolated from termite guts. Termites have been reported with high cellulosic activities including many bacterial and fungal strains in their guts. The termites used for the extraction of cellulolytic bacteria and fungus were collected from our campus. The termites were taken out of their nests and were crushed with the help of mortar and pestle in 0.9% sterile saline solution under aseptic conditions. Suspension of the crushed sample was serially diluted and plated on 1% CMC and 1% cellulose powder containing Nutrient agar, Luria agar and Potato dextrose agar plates and incubated at two different temperatures i.e. 30 and 40°C, respectively. The isolated fungal and bacterial strains were identified at NCCS, Pune. Fungal strains were identified by ITS4 and ITS5 gene sequencing while bacterials were identified based on MALDI-TOF MS. To reduce the production cost of in-house cellulases two potential fungal strains namely *Aspergillus flavus* and *Aspergillus tubingensis* are selected for production of cellulases under solid state and submerged fermentation using synthetic media and wastewater generated during mild alkali pre-treatment are being tried as moistening agents.

Simultaneous micro-algal bio-remediation process of diary effluent and post-harvesting methods

Earlier, the out-door cultivation of *Ascochloris* sps in raw dairy wastewater and different methods of post-harvesting for micro-algal biomass separation were reported. In continuation, surface texture

of micro-algal cells was analyzed by field emission gun scanning electron microscopy coupled with energy dispersive analysis of X-ray spectroscopy (FEG-SEM/EDAX) (Nova NanoSEM450™, Make: FEI Ltd, Thermo Fisher Scientific). Samples mounted on aluminum stubs fixed with double-coated carbon tape were used in FEG-SEM. The vacuum chamber was maintained at 5 kV voltage and then analyzed at 10000x magnification. Optical and SEM results clearly revealed that the micro-algal cells adhere coherently to each other and promote flocculation due to the physiological changes in the medium with the addition of external chemical agents. Along with cell-cell binding we have detected binding of Fe^{+3} and Zn^{+2} to the cell membranes. But, with $ZnSO_4$ the micro-algal cells were deformed, and similar observation was also seen with $ZnCl_2$, while other sulphates and chlorides had shown no such effect.

An Algal Research Station has been created for pilot-scale cultivation and post harvesting of micro-algae. It houses an open raceway pond, high volume V-shape pond, vertical tubular photo-bioreactor, flat plate photo-bioreactor and column photo-bioreactor for cultivation. A continuous centrifuge has been installed having the capacity to harvest 750 L per h of micro-algal culture (Fig. 10).

Fig. 10: Pictorial view of Algal Research Station

1.1 Gasification

Introduction of SPRERITECH fluidized bed gasification system in poha making factories for improved efficiency and working environment

Three major districts of Gujarat viz. Anand, Ahmedabad and Navsari are considered as major hubs of poha making. These districts have~500 small and medium-scale rice processing factories. In this context, the poha factory plays a pivotal role in shaping the rural economy (Fig. 11).

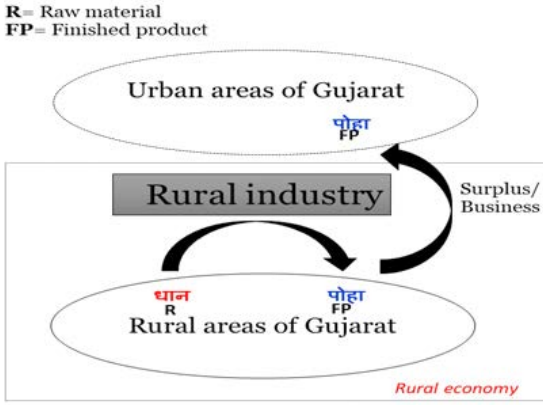

Fig. 11: Economic dynamics of poha industry

Most of these poha factories use wood and sawdust as fuel for roasting using conventional combustion methods. Nevertheless, short supply chain of fuel and low efficiency of the conventional combustor is a major concern as these can impact the economics of poha making. In addition, open combustion of loose biomass in poha making is creating environmental pollution because of fly-ash and particulate matter generation. During a field visit to M/s Swastik Poha factory at Umreth, it was observed that the health of people in- and around the factory and close by areas is getting adversely affected (Fig. 12). Furthermore, the operators in such industries are liable to suffer various respiratory problems.

These poha factories are unable to achieve a balance between good revenue generation and sustainable environment and health because of the in-efficient combustion of fuel and heat transfer in the existing roasters (Fig. 12 and 13).

Fig. 12: Open combustion of sawdust in M/s Swastik Poha factory, Umreth, Gujarat

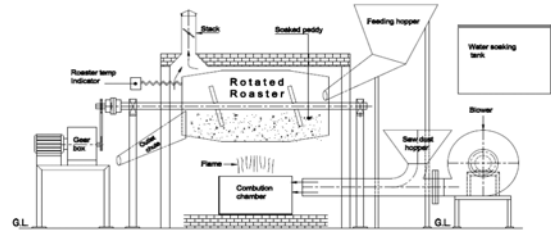

Fig. 13: Schematic representation of a poha factory depicting roaster and combustion chamber

In this context, fluidized bed gasification (FBG) technology is found suitable for powdery biomass such as rice husk, sawdust and crop residues to provide a solution to replace the conventional combustion technology that is used for open burning of loose biomass i.e. sawdust and rice husk.

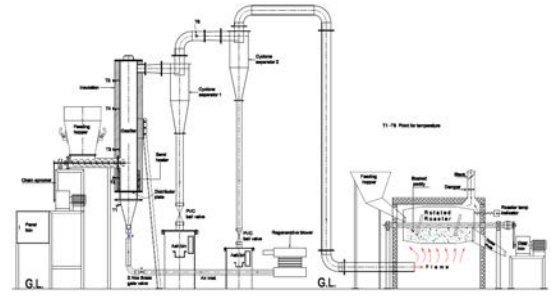

Fig. 14: Schematic representation of a developed FBG to meet thermal need of poha factory

Optimization of the FBG system for 80-100 kg h^{-1} is in progress. This concept will demonstrate a holistic impact of technology on improvement of human health and reduction of environmental pollution.

Gasification of torrefied biomass

Torrefaction is a mild pyrolysis process. During torrefaction, specific biomass undergoes Maillard reactions to obtain better quality fuel. Torrefied material is a better quality fuel compared to its unprocessed counterpart. SPRERI has developed the methodology for different biomass such as rice husk and sawdust (Fig. 15). The obtained torrefied materials were subjected to gasification process using a fluidized bed gasifier. The Tar and SPM content in producer gas is found reduced by 30-35% in the case of torrerified biomass gasification.

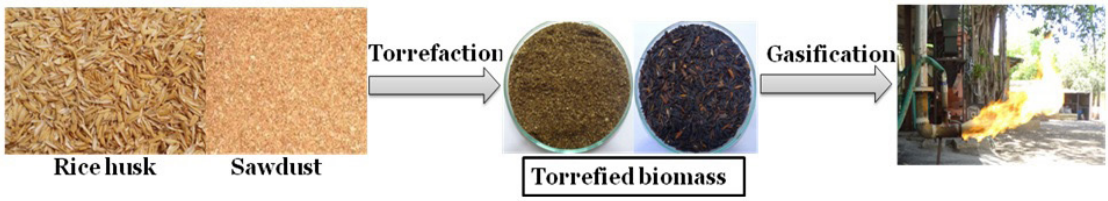

Fig. 15: Gasification of torrefied rice husk and sawdust in a fluidized bed gasifier

3.2. Pyrolysis

Towards an agricultural residue based bio-refinery via continuous pyrolysis

Utilization of surplus agricultural residues as raw materials in a bio-refinery is a promising alternative to fossil resources for production of bio-energy. Converting agro-residues to bio-energy can be a major step in management of this biomass.

In the above context, different bio-energy conversion processes such as combustion, gasification, pyrolysis and anaerobic fermentation are known for converting ligno-cellulosic biomass into gaseous and liquid fuel.

SPRERI has designed and developed a vertical moving bed type pyrolysis reactor. Using the SPRERITECH continuous pyrolysis system, different agro residues such as groundnut shells and cotton stalks were pyrolyzed (Fig. 16). This process yielded bio-oil, pyro-gas and bio-char. The bio-oil yield from groundnut shell and cotton stalk were 34-40%, respectively. After obtaining the liquid phase, bio-oil was separated from it via gravity separation. The bio-oil in the remaining aqueous phase was recovered by extraction using methanol as a solvent. After separation and isolation of the bio-oil, its calorific value (CV) and physico-chemical

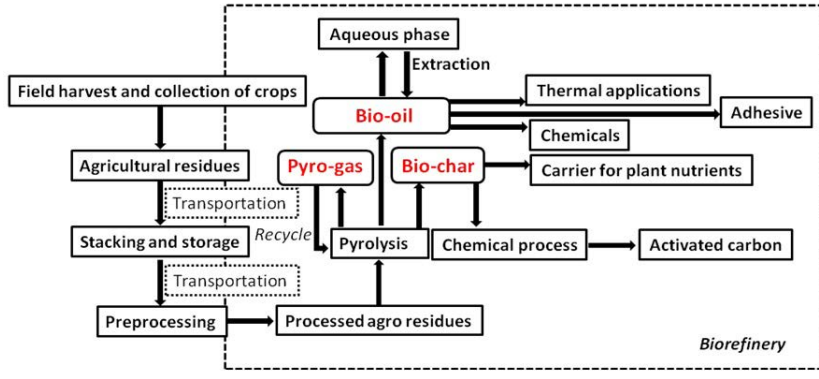

Fig. 16: Conceptual representation of an agricultural residues based bio-refinery via continuous pyrolysis

characterization were carried out. In addition, it was subjected to 1H NMR, FT-IR and GC-MS analysis. The bio-oil was found to contain fourteen different classes of compounds including acids, alcohols, aldehydes, ketones, phenols, furans and aromatics (Fig. 17). In total around 86 organic compounds were identified using GC-MS.

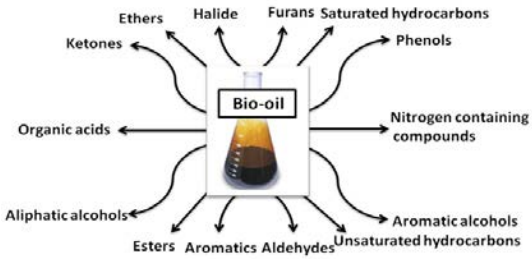

Fig. 17: Identification of different classes of organic compounds in bio-oil using ^{1}H NMR, ^{13}C NMR, FT-IR and GC-MS

Development of a bio-oil based burner

Bio-oil or pyrolysis oil as an alternative for fossil-fuels can be prepared from agro industrial residues such as groundnut shells, and cotton stalk by heating the biomass at high temperatures in the absence of oxygen and subsequent condensation of vapors that are released. It is a potential fuel that can be used for thermal applications such as in industrial boilers and small & medium-scale heating applications.

Fig. 18: A bio-oil based burner developed at SPRERI

A bio-oil burner set-up has been developed and retrofitted to the boiler for thermal application (Fig. 18). The burner ran satisfactorily with consumption rate of 23.3 kg h^{-1} of bio-oil derived from pyrolysis. Initially during start-up 1.2 kg of LPG was used to heat the burner to avoid oil deposition. Detailed work on utilization of bio-oil in a developed burner is in progress.

4.1 DST Core Support Programme

A family size solid-state toilet linked bio-gas plant of 2 m^3 d^{-1} capacity has been constructed and commissioned at 13 selected farmer sites in Zalasag village of Mahisagar district. Beneficiaries and their family members appeared fully satisfied with the quantity and quality of the gas output and performance of their plants. The gas at all the sites is being used for thermal applications i.e. cooking and heating water. Data collection on performance and socio economic impact is under progress.

After designing and fabrication of the dhabha size IBCS (Model: 240-FCT-M), the performance and operational parameter testing was done as per BIS standards. Data on performance for natural-draft and forced-draft is given in Table 10.

Field testing of natural and forced-draft cookstoves was done at road-side eateries located at Boriavi villages of Anand district (Fig. 19). The base data for both users has been collected.

Fig. 19: SPRERI dhabha size forced-draft and natural-draft IBCS

Table 10: Performance of dhabha size IBCS

Sr. No.	Type	Power rating (kW)	Efficiency (%)
1	Forced-draft	5.75	31.70
2	Natural-draft	3.50	27.50

The details on performance of forced and natural-draft cookstoves at two different locations are as shown in Table 11.

Table 11: Comparative for fuel used and cooking time of food items

Name of the users/village	Parameter	Average value		
		Before (Mud chulha)	With IBCS	% improvement
Maruti nandan restaurant, Boriavi (Forced-draft)	Fuel	Mixed fuel wood		
	Avg. quantity used/d	28 kg	17 kg	~ 39
	Cooking time for dish (Mug masala-15 kg)	30 min	18 min	~ 40
Rahul restaurant, Boriavi (Natural-draft)	Fuel	Mixed fuel wood		
	Avg. quantity used/d	29 kg	21 kg	~ 27.5
	Cooking time for dish (Patterveli bhajiya-1.5 kg)	10-12 min	5-6 min	~ 50

With the introduction of SPRERI dhabha size biomass cookstove, following are the observation and findings:

- Cost-saving: Rs. 1300 per month (Forced-draft) and Rs. 960 per month (Natural-draft)
- Feedback: In the case of forced-draft (i) a control is required for fan (ii) a battery back-up is required for power (iii) there were no issues related with operation and maintenance of the cookstove

For more data collection, monitoring of both the cookstoves is in progress. Simultaneously, identification of other interested road-side dhabha/hotels is in progress.

Double-pot IBCS with chimney

Thermal efficiency and burning rate were monitored for double-pot IBCS with chimney (Fig. 20) as per BIS standards and is shown in Table 12.

Fig. 20: Double pot cookstove

Table 12: Performance of the SPRERITECH cookstove without and with chimney

Description	SPRERITECH (160-NDS-F)		
	without chimney	with top plate and chimney	
	Single pot	*Double pot with chimney*	*Double pot with water heating at chimney*
Burning rate (kg h^{-1})	1.40	1.80	
Thermal efficiency (%)	28.00	25.04	27.47
Power rating (kW)	1.94	1.94	2.13

The temperature was recorded at the chimney outlet and was found in the range of 150-185°C. Further modification and data collection on indoor air quality data with and without chimney arrangement is in progress.

Natural day-light harvesting

Under enhancement of indoor daylight and ventilation in tribal/rural houses, 13 nos. of solar domes (Fig. 21) were procured from NB Institute for Rural Technology, Kolkata, under technology adoption scheme. The testing of the gadget and simultaneously selection of beneficiaries for field implementation is in progress.

Fig. 21: Solar dome for natural day-light harvesting

On the commemoration of 150th birth anniversary of Mahatma Gandhi, SPRERI organized a one-day awareness programme on **"**Water, Health and Sanitation" on 24 October, 2018. More than 60 women participated in the programme (Fig. 22).

Fig. 22: View of women participation in the programme organized by SPRERI

4.2 Rural Development Programme

Demonstration - cum - awareness programmes were organized in eleven villages of two districts (Asharma, Khadol, Nani Sankhyad, Moti Sankhyad, Chamara, Gambhira, Chhaganpura, Nava Pura, Tansia, Himmatpura and Dungarpura) of Gujarat and three villages of (Goriya Khandan and Thandla) of Madhya Pradesh (bordering Gujarat). Renewable energy technologies such as IBCS, toilet-linked bio-gas plant was included in the programme. Around 555 villagers took part in the demonstration programmes and interacted actively with SPRERI staff.

Demonstration of the improved biomass cookstove (190-NDS-L) in 12 villages of Pratapgarh, Rajasthan with the Foundation for Ecological Security (FES) was carried out for the villages located in their operational watershed clusters. Around 750 women farmers showed interest in the improved biomass cookstove which were provided by FES with the help of SPRERI.

Family size solid-state toilet linked bio-gas plants (2-4 m^3 d^{-1} capacity) were set-up and demonstrated at ten (10) selected farmer's sites in Munjkuva (1 no) and Shokhda (9 nos) villages of Anand and Vadodara districts (Fig. 23). Base-line data of all these users was collected. Five bio-gas plants were commissioned recently and the remaining will be commissioned soon.

Fig. 23: Views of toilet-linked bio-gas plant, conventional chulhas and bio-gas using by beneficiary at Munjkuva village

In addition, to celebrating 15 October as Mahila Kisan Divas, SPRERI organized an awareness programme with progressive farmers of Munjkuva village of Anklav Block in Anand district, Gujarat. The objective of organizing the program was to discuss the role of women in farming, women empowerment, issues related to health and nutrition, etc. More than 50 women participated in the program. The invited participants were progressive women farmers, members of the bio-gas committee and self-help group members of Munjkuva village. Renewable energy technologies were explained to the participants by the SPRERI team. In addition, they were also briefed about the benefit of the technologies and how women can adopt the technologies and become entrepreneur.

Implementation of 1000 nos. family size improved biomass cook-stoves for dissemination programme in Jharkhand state (JTDS- JTELP)

Under this project, 1000 nos. of family size natural-draft cookstoves (190-NDS-L) were fabricated, transported and distributed in four districts (Dumka, Godda, Pakur, Sahebganj) of Jharkhand (Fig. 24). A pre-implementation survey was conducted in two phases to understand the cooking energy pattern of the beneficiaries in Jharkhand. Data analysis is in progress.

पहाड़िया समुदाय के बीच धुंआ रहित चुल्हा वितरण

चुल्हा सौंपते विधायक।

बोरियो/संवाददाता। झारखंड आदिवासी विकास संस्था (जेटीडीएस) द्वारा सिटीजन्स फाउंडेशन कार्यालय में शनिवार को करमाटांड़, कवड़ा व आदरी पहाड़ के सैकड़ों पहाड़िया आदिम जनजातियों के बीच बोरियो विधायक ताला मरांडी ने धुआं रहित चुल्हे का वितरण किया। इस मौके पर सिटीजन्स फाउंडेशन कार्यालय से परियोजना समन्वयक कृष्ण मोहन श्रीवास्तव, जॅडर ऑफिसर सोनी मुर्मु व सामुदायक उत्प्रेरक राजकुमार रजक, सूरज रजक, अरविंद पंडित, साहिल मरांडी सहित अन्य मौजूद थे।

Fig. 24: View of chulhas used by villagers and distribution of IBCS at Jharkhand

Also, SPRERI successfully organized classroom training on 7 March, 2019 at Pakur, Jharkhand for capacity building and training for JTDS staff and users (Fig. 25). A total 60 JTDS district/block officials and village level resource persons attended the classroom training cum demonstration on operation and maintenance of IBCS.

Fig. 25: Classroom training programs for JTDS officials and CRPs demonstrated at village level

4.4 ORP on the solar tunnel dryer (walk- in type) for drying of fruits and vegetables in agro industry

Fifteen (15) agro-processing industries of Patan district including small Gruh Udyog based on spices and vegetable powder were contacted for implementation of the walk-in type solar tunnel dryer in their respective facilities.

M/s Geo-Fresh Organic, Sidhpur, District: Patan has shown interest in setting up a solar tunnel dryer and an MoU is signed with them after which a solar tunnel dryer was commissioned at their premises. The user has started drying Moringa leaves and beet root using the solar tunnel dryer. Performance monitoring is in progress (Fig. 26).

Fig. 26: Walk-in type solar tunnel dryer at M/s Geo-Fresh Organic, Sidhpur

Consultancy Projects

- Building adaptive capacity through the scaling-up of renewable energy technologies in rural Cambodia (S-RET), M/s KOSOL Energie, Ahmedabad
- Performance monitoring & third-party certification of solar cold room, M/s Ice Make Refrigeration Ltd., Gandhinagar
- Proposal for developing a green process for recycling synthetic fiber from blended fabric (Phase-I), M/s Arvind Textiles Ltd. Ahmedabad
- Pre-feasibility bio-methanation studies on Australian sugarcane, M/s Muniseva Ashram, Waghodia, Vadodara
- Pre-feasibility bio-methanation studies on textile sludge samples, M/s Arvind Envisol, Ahmedabad
- Pre-feasibility study of gasification of municipal solid waste in a fluidized bed gasifier, M/s Agro Power Gasification Pvt. Ltd.
- Prefeasibility study of pyrolysis of the agro-residue available in Gujarat State, M/s Saraswati Buildcon

Memorandum of Understanding (MoU) and Technology Transfer

- An MoU has been signed with M/s Geo-fresh Organic, Sidhpur, Gujarat for the implementation of Walk-in type solar tunnel dryer.
- An agreement was signed with Shree Krishna Hospital and Medical Research Center, Karamsad for the implementation of 100 Kg d^{-1} kitchen waste based bio-methanation plant (2 nos.).
- An MoU was signed with M/s Goodrich Cereals, Karnal, Haryana for the implementation of 1,50,000 LPD potato wastewater based bio-methanation plant.

Recognitions & Academic Activities

- A certificate of appreciation and cash award of Rs. 10,000/- was awarded to Er. Balasubramanian Velmurugan and team for the research paper entitled "Bio-gas from dairy scum - A case study of Vidya dairy" by Indian Dairy Association during the 47th Dairy Industry Conference at Patna on February 9, 2019.
- Er. Balasubramanian Velmurugan was appointed as a project review committee member for the project "Development and validation of technology for production of high-density bio-coal from rice straw and other agri-biomasses" by the Office of the Principal Scientific Adviser to the Government of India.
- Dr. Gaurav Mishra was appointed as a project review committee member by DST, GoI.
- Dr. Gaurav Mishra was appointed as an expert committee member of Bridging the Urban and Rural Divide and Council for Science and Technology for Rural India programme of DST, GoI.

Post-graduate dissertations

Title	Simulation and experimental analysis of thermal storage based solar cooker
Student	Mr. Milan Sojitra (6.8.2018 - 18.6.2019)
Programme	M Tech (Thermal Engineering)
Institute	ADIT College, VV Nagar

Title	Thermal energy storage with encapsulated PCM and its environmental applications
Student	Ms. Nirali Dudhrejiya (21.9.2018 - 30.4.2019)
Programme	M Tech (Environmental Engineering)
Institute	BVM Engineering College, VV Nagar

Title	Feasibility study of solar evacuated tube with heat pipe collector for cooking application
Student	Mr. Kaushal Bhadresa (21.9.2018 - 30.4.2019)
Programme	M Tech (Environmental Engineering)
Institute	MS University, Vadodara

Title	Designing rooftop solar PV system for SPRERI
Student	Mr. Parmar Mahesh L (1.12.2018 - 25.4.2019)
Programme	M Sc (Renewable Energy)
Institute	ISRRE, SP University, VV Nagar

Title	Experimental analysis of thermal and electrical performances of PV/T air collector system under forced convection
Student	Ms. M Nandini (4.12.2018 - 28.3.2019)
Programme	M Sc (Renewable Energy)
Institute	ISRRE, SP University, VV Nagar

Title	Energy audit on cotton farming in Gujarat
Student	Mr. Hirapara Ravikumar V (24.1.2018 - 23.5.2018)
Programme	B Tech (Agricultural Engineering)
Institute	CAET, NAU, Dediapada

Title	Energy audit on groundnut farming in Gujarat
Student	Mr. Katheriya Gaurav R (24.1.2018 - 23.5.2018)
Programme	B Tech (Agricultural Engineering)
Institute	CAET, NAU, Dediapada

Title	Performance monitoring of biomass combustor
Student	Mr. Chauhan Vishalkumar S (1.2.2018 - 31.5.2018)
Programme	B Tech (Agricultural Engineering)
Institute	CAET, AAU, Godhra

Title	Micro-algae for industrial wastewater treatment and bio-diesel production
Student	Ms. Preeti Sant (21.9.2018 - 30.4.2019)
Programme	M Tech (Environmental Engineering)
Institute	BVM Engineering College, VV Nagar

Publications

Kiran Kumar Adepu, Shaishav Sharma, Aesha Patel, Gaurav Dixit, Ekta Shah (2019) Comprehensive evaluation of micro-algal based dairy effluent treatment process for clean water generation and other value added products. *International Journal of Phytoremediation* 21, 519-530.

Balasubramanian Velmurugan, Madhuri Narra, Darshan Rudakiya, Datta Madamwar (2019) Sweet sorghum: A potential resource for bio-energy production. *In: Refining Biomass Residues for Sustainable Energy and Bioproducts. Elsevier.* DOI: 10.1016/B978-0-12-818996-2.00010-7.

Kiran Kumar Adepu, Ekta Shah, Aesha Patel, Shaishav Sharma, Gaurav Dixit (2018) Physico-chemical characterization, evaluation of neat and aqueous mixtures of choline chloride + lactic acid in ligno-cellulosic biomass fractionation, enzymatic hydrolysis and fermentation. *Journal of Molecular Liquids* 271, 540-549.

Kiran Kumar Adepu, Shaishav Sharma, Ekta Shah, Bhumika Parikh, Aesha Patel, Gaurav Dixit, Sunil Gupta, Jyoti Divecha (2018) Cultivation of Ascochloris sp. ADW007-enriched micro-alga in raw dairy wastewater for enhanced biomass and lipid productivity. *International Journal of Environmental Science and Technology* 16, 943-954.

Shaishav Sharma, Kiran Kumar Adepu (2018) Role of natural deep eutectic solvents (NADES) in ligno-cellulosic feedstock pre-treatment for integrated bio-refinery and bio-processing. *In: Recent Advancements in Biofuels and Bioenergy Utilization. Springer Nature* 73-109.

Ramkishore Singh (2018) Dye-sensitized solar cell technology: recent development and advancement. *In: Low Carbon Energy Supply: Green Energy and Technology. Springer Nature* 221-250.

Open House

The 11th **Open House** was organized at SPRERI from 15-16 February, 2019. The purpose was to provide a renewable energy platform for farmers, students, faculty and the community to develop an understanding and to create an awareness on different renewable energy technologies at SPRERI.

The programme began with a brief inaugural ceremony in which more than 400 higher secondary school students and teachers participated (Fig. 27). Shri Manishbhai S Patel, Vice-president, Charutar Vidya Mandal, Vallabh Vidyanagar was invited as the Chief Guest and in his inaugural address, he advised the youth to critically study various renewable energy devices on display and try to adopt suitable technologies in their lives, wherever possible.

Fig. 27: Open House inaugural by Shri Manishbhai S Patel and students learning about SPRERI technologies

More than 2800 participants, mostly students and their teachers from science, engineering, management and other disciplines belonging to 37 different institutions and farmers from all over Gujarat participated in the Open House. Scientists and technical staff of SPRERI explained the technologies and systems displayed in the Open House and interacted with participants on a one-to-one basis to provide clarifications to their queries.

Hari Om Ashram Prerit Young Scientist award

Every year SPRERI announces Hari Om Ashram Prerit Young Scientist/Engineer Award sponsored by Hari Om Ashram, Nadiad, commemorating the birth centenary of Pujya Mota for outstanding research in the field of renewable energy.

The Young Scientist/Engineer award for the period 2014-17 was conferred on Dr. Haider Ali**,** Associate Professor, IIT-D for his work "Development of biomass-derived platform molecules to produce high value bio-renewable products" by Shri Manishbhai S Patel during the inauguration ceremony of the "Open House" on 15 February. The award comprised a cash price of Rs 51,000/- and a certificate.

Hari Om Ashram Prerit Lecture

SPRERI has received an endowment from Hari Om Ashram, Nadiad towards a biennial Hari Om Ashram Prerit Lecture on Renewable Energy to honour distinguished persons who have made a valuable contribution in areas related to energy. Shri YB Ramkrishna, Member-Working group on Bio-fuels, Ministry of Petroleum & Natural Gas, New Delhi and Member-Apex Committee on Methanol Economy-NITI Aayog, New Delhi was invited to deliver the lecture on "Biomass based liquid & gaseous fuels-The new policy frame work and sustainable initiatives in India towards creating bio-economy" on 29 March, 2019 (Fig. 28). During his presentation he majorly emphasized the importance of the bio-fuels programme, the thrust areas and national policy on the bio-fuels programme in India. He also highlighted the progress on current 2nd generation bio-fuel (ligno - cellulosic ethanol) and covered a few important research areas such as bio-diesel, compressed bio-gas and drop-in fuels, bio-oil, waste to energy and methanol economy etc. More than 250 officials and faculty members from different

organizations and science and engineering colleges participated in the event.

Fig. 28: Hari Om Ashram Prerit Lecture

Brain Storming Session

SPRERI organized a One-day brain storming session on "Recent advances in production of 2G bio-fuel in India" on 10 July, 2018 at SPRERI, Vallabh Vidyanagar, Gujarat with financial support from GSBTM, Gandhinagar and M/s Chiti-chem Corporation, Vadodara and M/s Biolinx Labsystems Pvt. Ltd. Mumbai. Around 30-35 delegates experts involved in Bio-fuel challenge programme were invited from all over India to participate and discuss current practices, future strategies, bottlenecks, troubleshooting to overcome reliance of fossil fuels by using ligno-cellulosic biomass for the production of 2G bio-fuel in India. Two technical sessions were held covering major thrust areas i.e. Recent research advances for biomass to energy management and Cutting edge researchable areas for enzyme technology (Fig. 29).

Fig. 29: Experts and participants of one-day brain storming session on recent advances in production of 2G bio-fuel in India

Training Programme

GEDA, Gandhinagar sponsored a series of thirty (30) one-day awareness programmes on "Various aspect of renewable energy technologies" and "Renewable Energy Sources and Environment protection". The training programmes were conducted by SPRERI at MGIIRED, Amrol, Dist. Anand for Engineering colleges and ITI students, farmers and rural women. The objective of the programme was to create awareness among the youth and community about the importance and usefulness of renewable energy.

More than 1400 participants from engineering/polytechnic/ITI colleges and farmers have participated in the training programmes. SPRERI personals were involved in explaining various RE technologies and ongoing research in Renewable Energy to the participants and also provided clarifications to their quarries. A field visit was also organized to the technology park, RE mobile van and 1 MW solar PV power plant (located at MGIIRED - GEDA center, Amrol) for participants.

c

સ્પ્રેરી દ્વારા આમરોલમાં તાલીમ કાર્યક્રમ

આણંદ, તા.. ૨૭...

સરદાર પટેલ પુનઃ પ્રાપ્ય ઊર્જા અનુસંધાન સંસ્થાન (સ્પ્રેરી) વિદ્યાનગર દ્વારા આંકલાવ તાલુકાના આમરોલ ગામમાં બે દિવસનો તાલીમ કાર્યક્રમ યોજવામાં આવ્યો હતો. આ તાલીમ કાર્યક્રમનો વિષય પુનઃ પ્રાપ્ય ઊર્જા સંસાધન તકનીકોની ભારતમાં વર્તમાન પરિસ્થિતિ હતો.

તાલીમ કાર્યક્રમમાં એગ્રીકલ્ચરલ એન્જિનિયરીંગ કે કોલેજમાંથી ૧૦૦થી વધારે વિદ્યાર્થીઓ અને શિક્ષકો સાથે ગુજરાત કાઉન્સિલ ઓફ સાયન્સ અને ટેકનોલોજીના અધિકારીઓ પણ ઉપસ્થિત રહ્યા હતા. તાલીમ કાર્યક્રમનો શુભારંભ ગુજકોસ્ટના અધિકારીઓ દ્વારા કરવામાં આવ્યો હતો.

સ્પ્રેરી સંસ્થા...ના જુદા જુદા વિભાગોમાંથી સાયન્ટિસ્ટ, એન્જિનિયરો અને મુખ્ય વક્તા તરીકે આમંત્રિત ડો. વિશાલ સિંગ અને ડો. એસ. એસ. કપડી દ્વારા પુનઃ પ્રાપ્ય ઊર્જા સંસ્થાપનની તકનીકોના ભાવતના વર્તમાનમાં શું પરિસ્થિતિ છે અને આ તકનીકોના શો ગો. ઉપયોગ છે તે વિષય ઉપર ચર્ચા કરવામાં આવી હતી. આ વિષય સાથે પુનઃ પ્રાપ્ય સંસાધન તકનીકો જેમાં બાયોગેસ, બાયોએથના પ્રકાર, નિર્ધૂમ ચુલા તેમજ તેની સીર ઊર્જા, બીજા પુન. પ્રાપ્ય સ્રાપનોનું પ્રદર્શન કરી તેમજ તેની તકનીકી તથા તેનાથી થતા ફાયદાઓની માહિતી આપી હતી. આ ઉપરાંત કેન્દ્ર સરકાર તથા રાજ્ય સરકાર તરફથી મળતા અનેક વિવિધ યોજનાકીય લાભો અને સહાય વિશે પણ માહિતી અને માર્ગદર્શન આપ્યું હતું.

Published in Sardar Gujari Newspaper on dated – 21.11.2018

Fig. 30: (a) Registration of participants (b) Memento to experts (c) Published in Sardar Gujarati local newspaper

GUJCOST Gandhinagar sanctioned two (2) Nos. of one-day training-cum-workshop programme on "Current Scenario on Renewable Energy Technologies in India". Programme was specially designed for Agricultural University students and was organized at MGIIRED, Amrol, Dist. Anand from 19-20 November, 2018. Total 87 students and 6 faculties from Anand Agricultural University and Sardar Krushinagar Dantiwada Agricultural University participated in programme (Fig. 30). The training cum workshop programme covered various aspects under renewable energy technology. The workshop was therefore to widen the purview of renewable energy sources and subsequently the whole approach to capacitating the participants and assessing the understanding on renewable energy technologies. Also, participants visited the 1 MW solar PV power plant with farming followed by a valedictory and certificate distribution session with live interaction with the subject experts on renewable energy technology.

Conferences, Meetings & Workshops

International Conference

Sr. No.	Details of the programme	Date	Scientist/ Research staff/ Student
1	"Entrepreneurship in agriculture and renewable energy sector", Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola Delivered a keynote speech on • Entrepreneurship opportunities in renewable energy: solar energy conversion technologies	March 15-16, 2019	Dr. Ramkishore Singh
2	"Environmental pollution and its control (EPIC-2019)", Govt. Engineering College, Banswara Presentation on • An integrated micro-algae based bio-refinery • Sustainable valorization of sawdust via batch and continuous pyrolysis • Melting behavior of nitrate salt as phase change material and its environmental application	February 18-20, 2019	Er. Preeti Sant Er. Bhavin Soni Er. Nilali Dudhrejia
3	"Energy storage technologies and systems (ICOEST 2018)", Suresh Gyan Vihar University, Jaipur Presentation on • Encapsulation methods and processes for phase change materials: an overview • CFD analysis of solar thermal storage device	November 23-25, 2018	Er. Nirali Dudhrejia Er. Milan Sojitra
4	"Women in science and technology: creating sustainable career", BVM Engineering College, VV Nagar Presented paper on • Performance monitoring of PV/T based solar collector for dual output	June 28-30, 2018	Er. Farha Tinwala

National Conference

Sr. No.	Details of the programme	Date	Scientist/Research staff
1	National seminar on "Climate change and sustainable development: facts, impact & perspective", Faculty of Social Work, MS University, Vadodara Delivered a talk on • Climate change mitigation - the role of renewable energy	March 15, 2019	Dr. Gaurav Mishra

Sr. No.	Details of the programme	Date	Scientist/Research staff
2	4th UGC national conference on "Current trends in biological sciences - III (CTBS -2019)" Presentation on • Cultivation of micro-algae in dairy effluent and its post harvesting processes for biomass production and clean water recovery • Banana stem for solid bio-fuel production • Cost effective production of cellulases in presence of black liquor using fungus *Aspergillus flavus*	February 11, 2019	Er. Balasubramanian Velmurugan Dr. Darshan Rudakiya Mrs. Kumud Macwan Mrs. Ekta Shah Ms. Manisha Harijan
3	Seminar on "Recent advancement in renewable energy", Sigma Institute of Engineering, Vadodara Delivered a lecture on • Prospects of energy from biomass	January 30, 2019	Dr. Gaurav Mishra
4	National symposium on "Green chemistry and technology for sustainability development (NSGC-2019)", GCET College, VV Nagar Presentation on • Waste to wealth: lignin valorization from agro-residual waste through natural deep eutectic solvents (NADES) approach	January 18-19, 2019	Er. Gaurav Dixit
5	All India seminar on "Energy management and audit", BVM Engineering College, VV Nagar Delivered a lecture on • Energy audit and energy conservation in buildings	October 26, 2018	Dr. Ramkishore Singh
6	Delivered lecture on "Renewable energy technologies", GCET College, VV Nagar	May 3, 2018	Er. Asim Kumar Joshi
7	Advances in chemical engineering and science (ACES-2019) conference, Indian Institute of Science Education and Research, Bhopal Presentation on • Valorization of value added products from lignocellulosic biomass for a sustainable next-gen NADES based bio-refinery • Pyrolysis of sawdust in a vertical moving type continuous reactor	March 7-8, 2019	Dr. Shaishav Sharma Er. Bhavin Soni

Invited Lectures

Sr. No.	Details of the programme	Date	Scientist/ Research staff
1	"Prospects and challenges of bio-energy for sustainable development", A&R Patel Institute of Integrated Study and Research in Biotechnology & Allied Sciences, VV Nagar	March 14, 2019	Dr. Shaishav Sharma
2	"Circular economy approach for bio-refineries: prospects and limitations", NV Patel College of Pure & Applied Sciences, VV Nagar	February 28, 2019	Dr. Sanjib Kumar Karmee
3	"Renewable energy from biomass" in one week short term training programme on "Energy conservation and management", B&B Institute of Technology, VV Nagar	January 28, 2019	Dr. Gaurav Mishra
4	College of Agricultural Engineering & Technology, AAU, Godhra • Prospects of organic waste utilization for bio-refineries in India • Prospects and challenges for liquid bio-energy towards sustainable development • Potential of solid waste utilization as source of refuse derived fuel energy	December 17, 2018	Dr. Sanjib Kumar Karmee Dr. Shaishav Sharma Er. Ashwin Tirpude
5	GUJCOST and DST sponsored one-week training programme "Transferring technology: rural development through technology transfer for better living", B&B Institute of Technology, VV Nagar	November 11, 2018	Er. Ashutosh Negi
6	"Renewable energy and women empowerment", Milk collection center, Munjkuwa	October 15, 2018	Er. Samir Vahora Mrs. Shweta Verma
7	"Women the key holders to promote sustainable environment", BVM Engineering College, VV Nagar	October 5, 2018	Mrs. Shweta Verma
8	"SPRERI technologies to HUDCO officials", Petlad	September 30, 2018	Dr. Ramkishore Singh Er. Samir Vahora
9	"Entrepreneurship and renewable energy for agricultural sector", AAU, Godhra	September 29, 2018	Dr. Gaurav Mishra
10	"Energy scenario and global environmental concerns" in the training programme on "New developments in energy management of dairy and food operations", Vidya dairy, Anand	August 6, 2018	Er. Balasubramanian Velmurugan
11	"Importance and status of renewable energy", GCET College, VV Nagar	April 17, 2018	Dr. Gaurav Mishra

Workshops/Meetings

Sr. No.	Details of the programme	Date	Scientist/Research staff
1	Participated in the discussion on "Round table on renewable energy for agriculture" and rural enterprise organized by Innovative Through Forum, Ahmedabad	February 23, 2019	Dr. Madhuri Narra
2	Annual review workshop of consortium research project on "Energy from agriculture" • Presentation of annual progress report and new project proposals	February 11-12, 2019	Dr. Gaurav Mishra Dr. Madhuri Narra Dr. Sanjib Kumar Karmee
3	Presented progress report of DST Core in Group Monitoring Workshop, Forest Research Institute, Dehradun	February 5-6, 2019	Dr. Gaurav Mishra Er. Samir Vahora Er. Ashutosh Negi Mrs. Shweta Verma
4	Attended a workshop on "Project formulation: climate change adaptation and mitigation", Deutsche Gesellschaft fur Internationale Zusammenarbeit, National Bank for Agriculture and Rural Development, Bankers Institute of Rural Development and Centre for Climate Change, Jaipur	February 4-8, 2019	Dr. Madhuri Narra
5	Attended one day "National workshop on patents: concepts and practice", NV Patel College of Pure & Applied Sciences, VV Nagar	January 29, 2019	Er. Balasubramanian Velmurugan Dr. Kiran Kumar Adepu Dr. Ramkishore Singh Dr. Sanjeeb Kumar Karmee Er. Samir Vahora
6	22nd Workshop of All India Coordinated Research Project on "Energy in agriculture and agro-based industries", ICAR-Central Institute of Agricultural Engineering, Bhopal • Presented progress reports for 17-18 and proposed programme for 18-19 in respect of solar energy, bio-conversion, thermo-chemical conversion, liquid bio-fuels, demonstration of RE systems and energy management in agriculture activities	December 10-12, 2018	Dr. Gaurav Mishra Dr. Kiran Kumar Adepu Dr. Madhuri Narra Dr. Ramkishore Singh Dr. Sanjib Kumar Karmee Er. Samir Vahora Er. Jignesh Makwana
7	Presented annual progress report of the project entitled "Development of an integrated process for co-production of liquid/gaseous bio-fuel from pre-treated lignocellulosic biomass" at GSBTM, Gandhinagar	December 7, 2018	Dr. Madhuri Narra

Sr. No.	Details of the programme	Date	Scientist/Research staff
8	Delivered an expert lecture on "Smart & sustainable technologies for infrastructure development" during one week short term training programme organized by BVM Engineering College, SPRERI, VV Nagar	December 3, 2018	Dr. Madhuri Narra
9	Delivered an expert lecture during one day training cum workshop programme on "Current scenario on renewable energy technology in India" sponsored by GUJCOST, Amrol	November 19, 2018	Dr. Madhuri Narra
10	Participated in workshop organized as a part of World habitat day celebration under the theme of "Municipal solid waste management", ADIT College, VV Nagar	October 5, 2018	Er. Samir Vahora
11	Participated in ICAR short course on "Innovative applications of renewable energy technologies for rural sector", Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola	October 1-10, 2018	Er. Ashutosh Negi
12	Attended Vadodara zonal workshop on "Swachh Survekshan" programme organized by Nagarpalika, BVM Engineering College, VV Nagar. Delivered a presentation on • "SPRERI waste to energy technology offerings for rural sector"	September 24, 2018	Dr. Gaurav Mishra Dr. Madhuri Narra
13	Attended brain storming workshop on "Employment generation through renewable energy - a scope in agricultural education system" Delivered a lecture on • Skill enhancement in agricultural education system" prospective for entrepreneurship in renewable energy" at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola	September 15, 2018	Dr. Gaurav Mishra
14	Participated in round table discussion on Guiarat-Colorado Energy Partnership Daialogue organized by Center for stragetic and International studies and the Shakti Sustainable energy Foundation	September,11 2018	Dr. Madhuri Nara Dr. Ramkihsore Singh
15	Participated in the national workshop on "Enhancement of farmers income through post-harvest management" organized by Indian Society of Agricultural Engineers, Anand Chapter and AAU	August 28, 2018	Dr. Gaurav Mishra

Sr. No.	Details of the programme	Date	Scientist/Research staff
16	Trained and demonstrated the operational procedures of solar bio-gas hybrid refrigeration system staff of bio-energy department, AAU, Anand	June 26, 2018	Er. Asim Kumar Joshi
17	Project review meeting on consortium research projects on Energy from Agriculture at SPRERI, Vallbh Vidyanagar • Progress report presentations of on-going projects	July 11, 2018	Dr. Gaurav Mishra Dr. KC Pandey Dr. Anil Kumar Dubey Er. Velmurugan Balasubramanian Dr. Kiran Kumar Adepu Dr. Madhuri Narra Dr. Ramkishore Singh Er. Samir Vahora Er. Asim Joshi Er. Jignesh Makwana Er. Farah Tinwala
18	Delivered lecture on "Renewable energy technologies", GCET College, VV Nagar	May 3, 2018	Er. Asim Kumar Joshi

Visitors to the Organization

- Shri K Karuppasamy, Officer - HR from Cavinkare, Kanchipuram visited on May 15, 2018.
- Mrs. Hiral Thaker, Chief Officer, Petlad Nagar Palika, Petlad visited on July 4, 2018.
- Shri Rajan Rawal, Executive Director, Centre for Advanced Research in Building Science and Energy, CEPT University, K.L. Campus, Navarangpura, Ahmedabad visited on July 7, 2018.
- Mr. Anand Vivek, COO and his team from Shree Krishna Hospital, Karamsad visited on July 16, 2018.
- Shri Dinesh Yadav, Director and CEO, Arvind Mill, Ahmedabad visited on August 8, 2018.
- Shri Sumit Kumar Ghosh, Chairman, Shellac and Forest Products Export Promotion Council, Kolkata visited on September 10, 2018.
- Shri Narendra J Zende, Research Director & Centre In-charge, ARTI, Phaltan visited on September 17, 2018.
- Prof. Shrikant J Wagh, Principal, Gujarat Power Engineering & Research Institute, Mehsana visited on September 24, 2018.
- Shri Shwetal Shah, Technical Advisor, Climate Change Department, Gandhinagar visited on October 5, 2018.
- Dr. JS Samra, Chief Executive Officer (Retd.), National Rainfed Area Authority, Ministry of Agriculture, Chandigarh visited on November 30, 2018.
- Shri Chandresh Shah, Head - ICT Infrastructure, Tata Power Company Ltd. Mumbai visited on December 17, 2018.
- Er. Ravinder Gaur, Scientist-D and Member-Secretary (State S&T Programme), TDT Division, Department of Science and Technology, New Delhi visited on January 18, 2019.
- Shri Mayank Patel, CEO, Centre for Advancing and Launching Enterprises (CrAdLE), Entrepreneurship Development Institute of India, Bhat, Gandhinagar visited on January 22, 2019.
- Dr. Jay Shankar Das, Joint Director, Gujarat Biotechnology Research Centre, Dept. of Science & Technology, GoG, Gandhinagar visited on February 13, 2019.
- Mr. Elad Itzkovitch and his colleagues from Israel visited on February 26, 2019.
- Shri Shwetal Shah, Technical Advisor and Shri Mukesh Shah, Joint Secretary, Climate Change Department, Gandhinagar visited on March 1, 2019.
- Mr. Yaswanth Tippireddy, Managing Trainee, Godrej Agrovet Limited, Mumbai visited on March 2, 2019.
- Dr. Manoj Mishra, Centre for Pastoralism, Ahmedabad visited on March 5, 2019.
- Shri SB Dangayach, Founder Trustee, Innovative Thought Forum, Ahmedabad visited on March 5, 2019.

- Dr. Gaurav Mishra, Director

Solar Energy Division

- Dr. Ramkishore Singh
- Er. Farah Tinwala
- Er. Jigar Andharia
- Mr. Mahendra Padhiyar
- Mr. Mukesh Jadav
- Er. Asim Kumar Joshi
- Er. Arun Bollavarapu
- Er. Sayali Rajale
- Mr. Prakash Machhi

Bio-Conversion Technology Division

- Dr. Kiran Kumar Adepu
- Dr. Madhuri Narra
- Dr. Anil Prajapati
- Er. Gaurav Dixit
- Ms. Nivedita Iyer
- Mrs. Ekta Shah
- Mrs. Aesha Patel
- Mr. Harman Parmar
- Er. Balasubramanian Velmurugan
- Dr. Shaishav Sharma
- Dr. Darshan Rudakiya
- Ms. Deepti Davla
- Mrs. Kumud Macwan
- Ms. Manisha Harijan
- Mr. Ashok Harijan
- Mrs. Manjula Vadhel

Thermo-chemical Conversion Technology Division

- Dr. Sanjib Kumar Karmee
- Er. Jignesh Makwana
- Er. Urvish Patel
- Er. Pradeep Kumar Budde
- Er. Ashwin Tirpude
- Mr. Ashok Patel

Technology Transfer & Extension Division

- Er. Samir Vahora
- Er. Kamal Trivedi
- Mrs. Shweta Verma
- Mr. Minesh Suthar
- Er. Ashutosh Negi
- Er. Ajinkya Hable
- Er. Kalu Kachchava
- Mr. Shailesh Solanki

Administration

- Mr. Kailas Trivedi
- Mr. Hitesh Dalwadi
- Mrs. Aida Mascarenhas
- Mr. Shaivel Dalwadi
- Mr. Bhupendra Prajapati
- Mr. Ramesh Bhoi
- Mr. Parshottam Harijan
- Mr. Ishwar Harijan
- Ms. Pragna Dave
- Mr. Harshad Suthar
- Mr. Hasmukh Vaghela
- Mr. Jayesh Parmar
- Mr. Dahya Harijan
- Mr. Rajesh Machhi
- Mr. Bhupat Parmar

Balance Sheet

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE - VALLABH VIDYANAGAR
BALANCE SHEET AS ON - 31 - 03 - 2019

FUNDS & LIABILITIES	2018	2019	ASSETS	2018	2019
CAPITAL FUND			**FIXED ASSETS**		
As per last year	**1082669.20**	**1082669.20**	**1. Furniture & Fixtures**	**249808.62**	**249808.62**
			2. Electric Fittings	162350.85	162350.85
PROJECT FUND			**Add : During the year**	0.00	0.00
				162350.85	**162350.85**
			3. Mobile Phone	19600.00	19600.00
Balance from last year (-)	6243647.69	11449117.63	4. Institute Equip.(R & D / Others)	1071372.00	1071372.00
Add / Less during the year (-)	5205469.94	8226457.00	5. Jeep GJ-23A-5102	0.00	0.00
(Annexure - A) * (-)	**11449117.63**	**3222660.63**	6. Car GJ-23 AF 0282	585597.00	585597.00
			7. New Jeep - 488	834000.00	834000.00
				2922728.47	**2922728.47**
EAR MARKED FUND			**INVESTMENT**		
			1. Fixed Deposit	21000000.00	11217166.00
1. Building Fund Provision			2. Deposit in LIC - Graduity Scheme	6654387.55	7297380.39
Add : During the year				**27654387.55**	**18514546.39**
	3364376.00	**3364376.00**			
			LOANS & ADVANCES		
2. Depreciation Investment Fund	**455244.00**	**455244.00**	1. Tax Deduction at Source	712932.46	1050501.06
3. R & D Fund (As per last year)	6934138.73	7272538.73	2. Telephone Deposit	20313.00	20313.00
Add : During the year	338400.00	831109.10	3. CGM Deposit (Oil Diesel & Petrol)	12400.00	12400.00
Less : During the year **(Anne - D)**	**7272538.73**	**8103647.83**	4. Indian Oxyzen Ltd., Deposit	4252.94	4252.94
			5. Mobile Phone Deposit	4680.00	4680.00
DONATION			6. Broad Band Security Deposit	3000.00	3000.00
Balance from last year	1184001.00	1234001.00	7. Gas Cylinder Deposit	10350.00	10350.00
Add : During the year	50000.00	0.00	8. Security Deposit (GEB - New DP)	100920.00	100920.00
	1234001.00	**1234001.00**	9. Loan to Staff & Advance to Project	729642.00	729642.00
			10.Intrest Accrued	**422746.66**	**459923.16**
PROJECT EQUIPMENT			11. Gujcost to be recover	**0.00**	**24800.00**
				2021237.06	**2420782.16**
			BALANCE :		
Depreciated value of Equip.from last year	89437718.35	98370566.35	Bank Balance	7639871.51	9906999.32
Add : During the year	8932848.00	7774385.00	Cash Balance	179994.00	120519.00
Less : Depreciation Annex. C	**98370566.35**	**106144951.35**		**7819865.51**	**10027518.32**
DEPRECIATION FUND					
As per Block - Annexure - B	**5785898.30**	5947504.30			
LIABILITIES					
1. Contigent Development Fund	**133400.00**	133400.00			
2. Graduity Fund	**6654387.55**	7297380.39			
3. Endowment Fund -	1399979.75	1413979.75			
Add : During the year	70000.00	70700.00			
Less :	0.00	171405.00			
Annnexure - E	**1413979.75**	**1313274.75**			
4. Staff Welfare Fund	**184155.50**	**246296.50**			
5. Share & Care Fund	**152835.00**	**152835.00**			
6. Quiz Programme Fund	**58262.00**	**58262.00**			
7. Maintenance Fund (Core Grant)	**547179.00**	**547179.00**			
Extension activity fund	0.00	**236938.00**			
Income & Expenditure A/C SURPLUS / LOSS					
From Last/current Yr Balance Sheet	**252731.47**	630174.93			
Add / Less During the year-17-18	377443.46				
TOTAL					
Less - during the year - 2018-19		140268.19			
TOTAL	**630174.93**	**489906.74**			
TOTAL	**40418218.59**	**33885575.34**	**TOTAL**	**38396981.53**	**33885575.34**

Accounts Officer
Sardar Patel Renewable Energy Research Institute
Accounts Officer

B. C. PATEL & CO. ANAND. Mem.No. 32231 Chartered Accountants

B. C. PATEL & CO.
Chartered Accountants
Mem.No. 32231
Chartered Accountants

Director
Sardar Patel Renewable Energy Research Institute
Director

Date :- 04.07.2019
Place :- Vallabh Vidyanagar

Abbreviations

%	Percentage
AAU	Anand Agricultural University
ADIT	AD Patel Institute of Technology
AHR	Anaerobic Hybrid Reactor
AICRP	All India Co-ordinated Research Platform
ARS	Algal Research Station
BVM	Birla Vishvakarma Mahavidyalaya
CAET	College of Agricultural Engineering & Technology
COD	Chemical Oxygen Demand
CRP	Consortia Research Platform
CSTR	Continuous Stirred Tank Reactor
CTAB	Cetyltrimethyl Ammonium Bromide
d	Days
DST	Department of Science and Technology
EAAI	Energy in Agriculture and Agro-Industries
EDAX	Energy Dispersive X-Ray Analysis
FEG	Field Emission Gun
GCET	GH Patel College of Engineering & Technology
GEDA	Gujarat Energy Development Agency
GoI	Government of India
GUJCOST	Gujarat Council of Science and Technology
HRT	Hydraulic Retention Time
ICAR	Indian Council of Agricultural Research
ISRRE	CL Patel Institute of Studies & Research in Renewable Energy
kL	Kilo Liter
L/kg	Litre per Kilogram
LPD	Litres per Day
mg/L	Milligram per Litre
MS	The Maharaja Sayajirao University of Baroda
NADES	Natural Deep Eutectic Solvents
NAU	Navsari Agricutural University
ppm	Parts per Million
RE	Renewable Energy
SEM	Scanning Electron Microscopy
SPRERI	Sardar Patel Renewable Energy Research Institute
SPU	Sardar Patel University
TS	Total Solids
TSC	Total Solids Concentration
$ZnSO_4$	Zinc Chloride

List of Technologies for Commercialization

- Thermal battery based solar refrigerator
- Stand alone type PV integrated solar low tunnel dryer
- Forced circulation solar cabinet dryer
- Solar based wax melting system
- Single axis sun tracker
- Solar-bio-gas based hybrid cold storage system
- Conversion of fruit and vegetable residue to bio-gas and manure
- Conversion of kitchen residue to bio-gas and manure
- Bio-gas generation from agro-industrial effluent
- Bio-methanation of dairy effluent scum
- Up-draft biomass gasifiers for thermal applications
- Open core down draft biomass gasifier systems for thermal and power applications
- Biomass combustor-cum-hot air generator
- Improved biomass cookstoves (batch and continuous operation)
- Movable platform type wood cutter for preparing feedstock for gasifier
- Glass roof tiles for natural sunlight in tribal rural houses

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