

SPRERI
Striving for Excellence

ANNUAL REPORT 2017-18



SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE

Contents

	Page
Important SPRERI Technologies available for use/commercialization	... 3
The Organization	
Vision and Mission	... 4
Highlights of the Year	... 5
Research and Development	
Solar Energy	... 6
Bio-Conversion	... 7
Thermo-Chemical Conversion	... 11
Training and Awareness Creation	
Training and Demonstrations	... 15
Open House	... 16
Hari Om Ashram Prerit Young Scientist Award	... 17
Post-graduate Dissertations	... 18
Consultancy	... 18
Memorandum of Understanding and	... 18
Technology Transfer	
Technology Demonstrations	
DST Core Support Programme	... 19
Rural Development Programme	... 20
Energy Audit	... 21
Improved Biomass Cookstove with Chimney	... 23
Patent Granted	... 24
Regional Test Centre	... 24
Human Resource Development	... 25
Participation in Meetings, Seminars and Conferences	... 26
Papers Published	... 30
Research Projects Pursued	... 31
Visitors	... 33
SPRERI Team	... 34
Balance Sheet	... 35
Abbreviations	... 36

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(As on 31st March 2018)

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- Ministry of New and Renewable Energy (MNRE), Govt. of India, New Delhi
- Navajbai Ratan Tata Trust, Mumbai
- Gujarat Council of Science and Technology (GUJCOST), Gandhinagar
- Gujarat Energy Development Agency (GEDA), Gandhinagar
- Gujarat State Biotechnology Mission (GSBTM), Gandhinagar

Important SPRERI Technologies available for use/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
- Updraft 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

Cover Page : Continuous Pyrolysis System

Back Page : SPRERI Team

The Organization

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 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 renewable energy technologies, among citizens, particularly the youth. Under graduate and post graduate students from all over the state visit SPRERI during Open House.

VISION

SPRERI, a leading organization for research and development of renewable energy technologies, focuses on sustainable biomass conversion and solar energy based solutions, which are technically efficient, economically viable, environment friendly and meet the needs of society.

MISSION

- To set-up a world class "Centre for advanced research in biomass conversion technologies"
- To develop environment friendly technologies for conversion of biomass into bio-fuels, energy (including electricity) and useful chemicals
- To develop technologies for utilization of bio-conversion waste
- To develop technologies for application of solar energy
- To develop business models for promoting use of renewable energy technologies
- To provide knowledge-based insights to influence policies and programmes of the government for utilization of biomass and solar energy technologies for meeting energy requirements
- To provide specialized training in renewable energy technologies to engineers and scientists and guidance and facilities to research students
- To provide extension support and consultancy to renewable energy programmes
- To test and evaluate renewable energy technologies

Highlights of the year

Renewable energy being one of the center-staged activities in Indian perspective has attracted more than US \$ 10.9 billion of investment in India during the year 2017. This directly correlates to the interest and favorable responses received in India, which also gets reflected on the ground level achievements. To highlight the commitment on renewable energy from India, Prime Minister of India along with President of France hosted 1st conference of the International Solar Alliance on 11th March 2018 to pave new directions and targets for renewable energy adoption on global level.

India has strengthened their position and stands among the top five countries in world in terms of installed and pipeline projects in renewable energy sector. In addition to this, through different research and development programmes funded by Government of India, a substantial reduction in the renewable energy generation cost has also been achieved. Due to these efforts, India, in last few years has witnessed new lowest tariffs of ₹ 2.44/kWh and ₹ 2.43/kWh for solar and wind-based projects.

SPRERI in-line with Government of India's broad agenda continues its research and development in renewable energy technologies. In one of the projects, to emphasize the importance of microalgae cultivation in dairy effluent stream to get clean water and the harvested biomass for production of bio-diesel/or value-added products, a detailed techno-economic evaluation of different systems has been done to disseminate it as an efficient & commercially accepted technology. On the other hand, in order to develop new efficient technologies, many new concepts on bio-gas and bio-ethanol are in research phase.

A patent (Patent no. 292125) has been granted for "Odour-free process for handling of organic solid wastes for bio-methanation and simultaneous production of solid bio-fuel/manure".

Under thermo-chemical conversion division, a 10 kg/h biomass torrefaction and pyrolysis system is fabricated, installed and is under rigorous testing using various agricultural feed stocks for bio-oil production. In addition, the conversion of bio-char obtained during the process to value-added product i.e. activated carbon is also underway. The double pot natural draft improved biomass cookstove is under development to cater the needs of rural/tribal populace.

Under a project sanctioned by DST on Efficiency enhancement of Scheffler dish solar concentrating technology, three different receivers were designed, tested and simulated. As a result, ~6% of the efficiency has been improved through design change in receiver.

MNRE supported, BIS approved and NABL accredited Regional Test Center at SPRERI completed testing of nine solar thermal devices during the year as per BIS/MNRE approved procedure. The devices tested included two flat plate collector-based water heaters, six evacuated tube collector-based solar water heaters and one solar box cooker.

The annual event "Open House" was organized at SPRERI on February 15-16, 2018. More than 3100 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".

Research and Development

Solar Energy

Efficiency enhancement of Scheffler dish solar concentrating technology

To access the thermal performance of Scheffler dish solar concentrating system, three different receiver designs *i.e.* a) dome type b) cavity type and c) flat type (shown in Fig. 1) were considered. For in silico studies, a Computational Fluid Dynamics (CFD) model was developed for receiver designs and Semi-Implicit Pressure-Linked-Equation (SIMPLE) scheme of the fluent software was used to perform the CFD simulation. In the simulations, a constant temperature boundary condition was applied on the receiver.

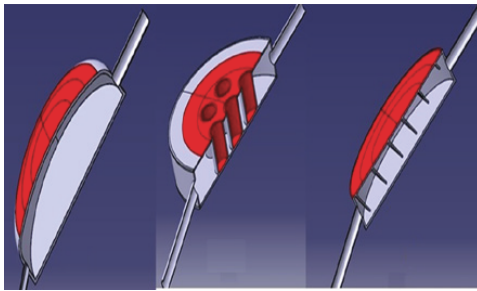


Fig. 1: Studied receiver designs

The modelling results were then validated against experimental data for the above designed receivers. The validation was performed by considering outlet temperature of the heated fluid measured at a sensor point (indicated by an arrow in Fig. 2) as one of the performance assessment parameters. Both simulation and experimental values of the temperature show similar pattern of changing with time. The simulation model overestimated the temperature values by 22% for temperature below 100°C, but above this temperature, the difference in simulation and experimental values are estimated less than 5%. Further, validated model was used to perform simulation on initially selected three

different receiver types, and temperatures at the outlet were estimated. The Figs. 2a and 2b show the temperature contours at different times during the simulation. The receiver with cavities performed better, in terms of increasing the fluid temperature, than the dome shaped and flat type receivers.

Shree Krishna Hospital, Karamsad was selected as user to install and demonstrate the system, with the improved receiver, at their premises. The system is planned to be installed at their one of the canteens for providing hot water/steam for cooking and cleaning purposes. Currently, they are using grid electricity/LPG for meeting their thermal energy demand in canteens as well as at other places.

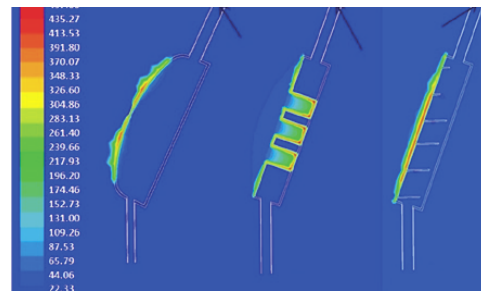


Fig. 2a: Temperature distribution of fluid inside three receiver designs at 0 second. Receiver wall is assumed at constant temperature 450°C

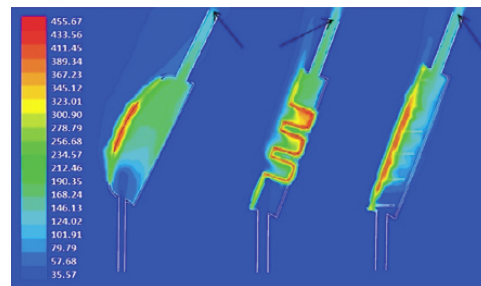


Fig. 2b: Temperature distribution of fluid inside three receivers after 300 seconds. Receiver wall is assumed at constant temperature 450°C

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

Conventional solar air collectors and PV

integrated solar air collectors (hybrid) have been tested under ambient weather conditions. The temperature was measured at three different positions (bottom, middle and top along the length of the collectors) in the path of heated air. During the experiments, global solar radiation, wind speed and ambient temperature were measured and observed in the range of 300-925 W/m², 0.08-0.15 m/s and 33-35°C, respectively. As expected, the temperature was found to be highest at the top with decreasing trend at centre and bottom in both the cases (Fig. 3). The difference in the centre and top sensor positions was observed lower than the centre and bottom sensor positions. The temperature at top was measured higher due to longer air residence time in contact with absorber (*i.e.* air travels from bottom edge of absorber to top edge of absorber by natural convection).

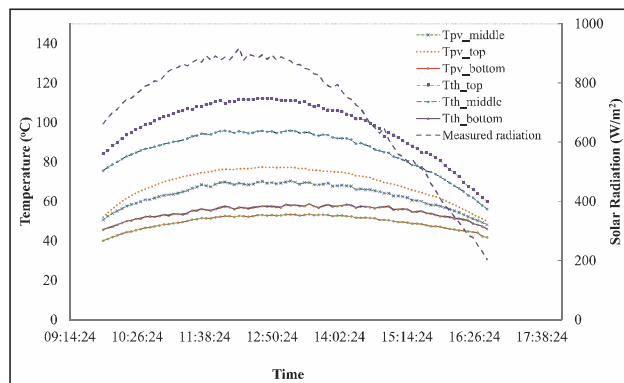


Fig. 3: Performance of different solar collectors for thermal output

The conventional thermal collectors yielded (~30%) higher temperature as compared to PV integrated collector due to higher transmissivity, which allows higher fraction of solar radiation directly on the black coated absorber sheet and resulted in higher air temperature. Further, the PV integrated glass cover was analysed for electrical output using solar PV analyser. The maximum

power output from the PV integrated solar collector was measured about 129 W at 815 W/m² with solar panel efficiency of 10.38%. The efficiency decreases on increasing the radiation as open circuit voltage (V_{oc}) decreases. The drop in V_{oc} can be seen as a result of increasing cell temperature on increasing the incident solar radiation.

Efficiency enhancement of solar thermal collectors by using nanofluids

Preliminary studies with various fluid-particle suspensions having higher spectral absorption were tried to observe the gain in heat capacity of fluids per unit mass under average solar radiation of 773 W/m² at steady state conditions for 6 h in 200 mL system. Distilled water was taken as a base reference fluid. Lignin extract obtained from ligno-cellulosic biomass after hydrolysis in Natural Deep Eutectic Solvent (NADES) was taken up for the experimental work. It was estimated that the percent rise in temperature difference for the extract was found to be 36.8% higher as compared to base reference. Different fluids or a mixture of metallic nano compounds are being explored for the base studies and then further scaled up to pilot level for studying the performance of the system with the conventional solar thermal based systems.

Bio-Conversion

Anaerobic digestion: Crop residues

Conventional bio-methanation processes for converting crop residue to bio-gas are batch mode and takes longer hydraulic retention time (HRT). As continuous systems are more advantageous SPRERI tried a new concept to check the potential of rice straw enzymatic hydrolysate as a carbon source for bio-gas generation using thermophilic anaerobic

hybrid reactor (AHR) (Fig. 4). In this, a reactor of 50 L capacity was designed and fabricated with packing of waste poly vinyl chloride (PVC) material as fixed film support. Initially, the AHR was operated in a continuous mode at 2 different HRT's (7 & 4 d) at 50°C. Chemical oxygen demand (COD) of the enzymatic hydrolysate was 106 g/L. The inlet COD of the rice straw enzymatic hydrolysate was maintained at 10 g/L. The initial findings revealed that at a lower HRT of 4 days the bio-gas yields (370-390 L/kg rice straw) were comparatively higher than the gas yields obtained earlier at SPRERI developed process in a batch mode (*i.e.* 325 L/kg rice straw) with a 20 days HRT. COD removal rate was in the range of 84-86% with a methane content of 75%. This is 13-17% higher than the earlier process with 59% methane content.



Fig. 4: Jacketed thermophilic anaerobic hybrid reactor

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 to the institute to evaluate its bio-methanation potential and to set-up a demonstration bio-gas plant in a

potato processing industry. Initially, potato wastewater was treated in two laboratory-scale AHR with 30 L and 31.5 L capacity using natural R1 (brick bats) and synthetic packing media R2 (pall rings) with inlet COD of 10 g/L and 2 different HRT's (10 & 7 d). Higher COD removal efficiency and bio-gas yield of 80.5% and 0.53 L/g COD fed, respectively were achieved in R2 at 10 d HRT with methane content in the range of 62-66%. Simultaneously, potato peels and cooked potato waste were treated in two laboratory-scale anaerobic reactors. Feeding was carried out in both the reactors at 10% total solids loading (TS) and HRT of 40 days. Bio-gas yields obtained were 78 and 123 L/kg of potato peels and cooked potato waste, respectively with methane content of 65%.

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. A total of eight (08) reactors (R1-R8) including two (02) control reactors were operated in batch mode to test the effect of anaerobic digestion on dairy effluent scum with and without pre-treatment. The conditions maintained for pre-treatment were (i) thermal pre-treatment at 121°C for 15 min and (ii) pH adjusted to 4 using hydrochloric acid. All the reactors were operated under mesophilic conditions (35°C) in a temperature controlled water bath at 7% TS with 1:1 substrate to inoculum ratio. After 30 days of digestion period, the bio-gas yield was 5% higher in R3 (thermal pre-treatment at 121°C for 15 min) than R2 (no pre-treatment).

Liquid bio-fuel: SPRERI cellulosic ethanol technology

Bio-ethanol from pre-treated corncob

In this study, a two-step pre-treatment with dilute HNO_3 and NaOH was performed efficiently on corncob to obtain cellulosic residue for production of ethanol. Based on the optimized conditions, pre-treatment of the corncob was carried out. Solid to acid ratio maintained was 1:5. To achieve higher reducing sugars, the acid pre-treated corncob was further pre-treated with low concentrations of NaOH, at 121°C for 15 min. Maximum delignification (80.20%) was achieved that resulted into increase in cellulose content by 97.50%.

The delignified solid residue rich in cellulose was used to produce ethanol using in-house thermotolerant yeast strain *Kluyveromyces marxianus* at 42°C with three different enzyme loadings i.e. 9, 15 and 21 FPU/g substrate for 96 h. Maximum ethanol yield (33.21 g/L) was obtained with 1% NaOH pre-treated cellulosic residue of corncob with 15 FPU/g substrate enzyme load at 87 h. As the enzyme loading increased from 9 to 15 FPU/g substrate there was a steady increase in ethanol yields, thereafter increase in enzyme loading above 15 FPU/g substrate did not show any positive effect may be due to saturation occurred above an optimum enzyme loading.

Techno-economic evaluation of SPRERI cellulosic ethanol technology

In-house designed 50 L capacity bench-scale horizontal rotary drum reactor was used to carry out ethanol production from crop residues. Low strength NaOH pre-treated rice straw was hydrolysed with in-house as well

commercial cellulases using simultaneous saccharification and fermentation process. Maximum ethanol yields were achieved with Cellic Ctec 2 enzyme supplied by Novozymes i.e. 26.83 g/L with a conversion efficiency of 81%. While the in-house cellulases yielded slightly lower ethanol concentration of 23.45 g/L with a conversion efficiency of 70.79%. Total energy requirement to produce 1 L ethanol from rice straw was approximately 8.4 kWh and the production cost of 1 L ethanol was ₹ 270/- in a bench-scale system.

Refinement of in-house cellulosic ethanol technology

This is a new project primarily addressing reduction in cost production of the in-house enzyme. The improvement in cost reduction is proposed to be achieved by refinement of the technology through adapting cost effective, bioprocess technology using low cost substrates using modified organisms and partly by development of enzyme cocktails. To begin with nucleotide sequence of the in-house fungal strain, *Aspergillus terreus* was analysed using various computational tools and softwares such as EMBOSS, BLAST (Expasy), ClustalW2 (EBI). Nucleotide and protein sequence of cellulase, xylanase and cellobiohydrolase was retrieved from UniprotKb and EMBL database. For protein sequence analysis, Compute pI/Mw (Expasy), AACompIdent (Expasy) tools were used. Based on the sequence homology, total seven genes were selected such as QOCEU4, QOCC84, QOCFS3, QOCBM8, QOCRF7, QOCMT2 and QOCFP1. Out of seven, two genes each are of cellulases and xylanases and three are of CBH (cellobiohydrolase) enzymes. Seven pairs of oligos were designed manually

using various other online tools. Designed oligos were validated by T_m cal, NEB cutter, Signal P, ORF finder and Snap gene and were synthesized from Eurofins Scientific. Genomic DNA and RNA of the fungal strain *Aspergillus terreus* was isolated by using NorGen BIOTEK kit. Purified DNA & RNA were analysed on agarose gel electrophoresis and stained with EtBr which was observed under UV transilluminator.

Pilot-scale pre-treatment of lignocellulosic biomass

SPRERI has developed a large number of NADES and have evaluated the pre-treatment efficiencies of lignocellulosic agro-residues, such as rice straw, wheat straw, groundnut shells, coconut fibers, etc. Based on the preliminary laboratory experiments on lignin removal efficiency, rice straw was selected for pilot-scale studies. An integrated pilot-scale reactor for biomass pre-treatment, hydrolysis and fermentation is shown in Fig. 5. After pre-treatment with NADES, the cellulose content was increased from 40 to 68%, with a delignification efficiency of 72%. The lignin was precipitated from the pre-treatment extract and further biophysical and biochemical studies revealed extraction of high-purity lignin in a single step. Enzymatic hydrolysis and ethanol fermentation were carried out with neutral NADES reagents where the biocompatibility of cellulose degrading enzymes and ethanol fermenting yeast strains were established. Maximum concentration of reducing sugars reached up to 169 g/L and glucose 90.3 g/L with a saccharification efficiency of 51.7%, while the ethanol content of 36.7 g/L was obtained within 36 h with a conversion

efficiency of 79.9%. The NADES reagent was recovered and reused for 3-pre-treatment cycles and no significant loss in pre-treatment efficiency was observed. An integrated green technology for biomass pre-treatment and cellulosic ethanol production with other value added by-products such as lignin and xylan was established.

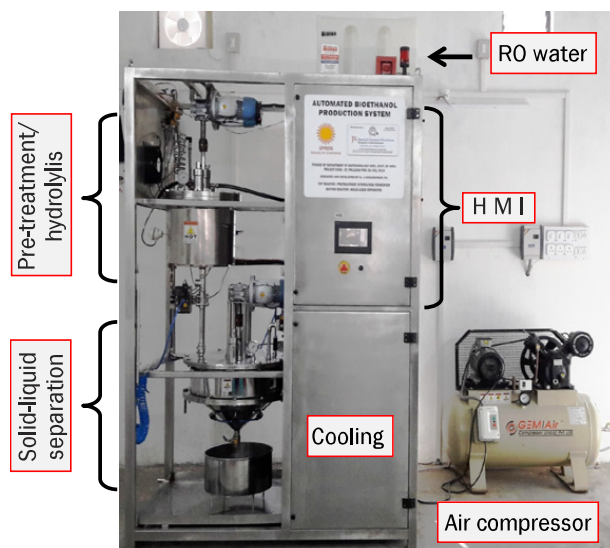


Fig. 5: Pilot-scale automated bioethanol production system developed at SPRERI

Microalgal technology

Bio-remediation of dairy effluent and post-harvesting methods

Earlier, the growth properties of *Ascochloris* sps ADW007 in raw dairy wastewater using simple semi-cylindrical open barrels in outdoor conditions were reported. In line, extensive evaluation of different methods of post-harvesting for microalgal biomass separation was carried out. Different chemi-flocculants (chlorides, sulfates, hydroxides, natural acids, detergents, carbonates, alcohols and other chemical agents) for separation of microalgal biomass and their effect on microalgal biomass removal efficiency was studied. Addition of 0.1% (v/v) of some of the flocculants to the culture medium resulted in >99% flocculation of the microalgal cells within 2-30 min, except

with NaOH, where it required 12 h incubation. In this study, FeCl_3 was found to have better flocculation efficiency than other flocculants tested due to its rapid flocculation time (~5 min).

After chemi-flocculation, the algal free water was introduced to sand and/or activated charcoal treatment and resulted in generation of clear and odourless water (Fig. 6). A 94-96% reduction of COD, 72-80% reduction of total nitrate and 80-97% reduction of total phosphate was observed after microalgal bio-remediation process of raw dairy wastewater. In addition, nearly 80% of clean water was recovered from microalgal treated dairy wastewater that was found to be amicable for irrigation, aquaculture, gardening, potable water generation and other industrial applications.

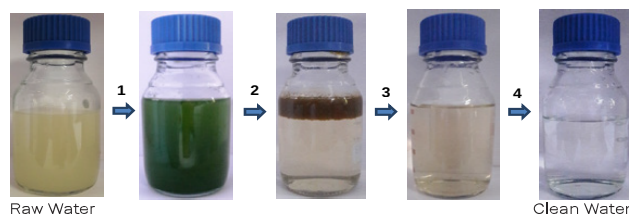


Fig. 6: Microalgal based bio-remediation of dairy effluent. Process steps include (1) microalgal growth (2) chemi-flocculation (3) microalgal biomass separation (4) activated charcoal filtration

Thermo-Chemical Conversion

Gasification

Fluidized bed gasification of torrefied bio-fuel for thermal and power applications

To improve the quality in terms of fuel

properties the biomass *viz.* rice husk and sawdust were torrefied at different temperatures for 60 min using SPRERI-TECH fixed bed pyrolysis reactor. Fig. 7 shows the images of the torrefied sawdust and rice husk at different temperatures. Table 1 shows the mass and energy yield of torrefied sawdust and rice husk.

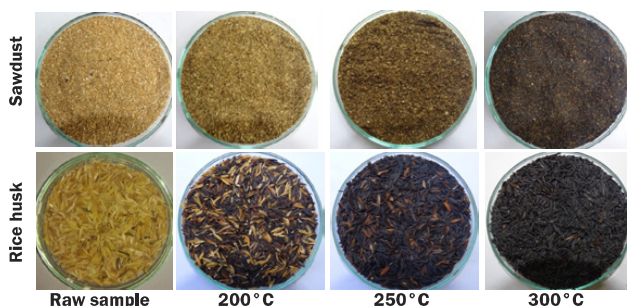


Fig. 7: Images of sawdust and rice husk torrefied at different temperatures

Optimum temperature of 250°C was selected for torrefied rice husk and sawdust biomass based on the benefits of increasing the heating value with counter balanced mass loss. Around 15-20 kg of the torrefied material of both the biomass were produced for gasification process in fluidized bed gasifier. Trials on raw and torrefied fuel for both biomasses in fluidized bed gasifier are under progress.

Pyrolysis

Fixed bed pyrolysis reactor for production of bio-oil

Different agro residues *i.e.* rice husk, bajra, bagasse, pigeon pea waste, groundnut shells and sawdust were pyrolyzed in SPRERI-TECH fixed bed pyrolysis reactor. Pyrolysis

Table 1: Energy and mass yield for sawdust and rice husk torrefaction at different temperature

Temperature (°C)	Sawdust				Rice husk			
	CV (kcal /kg)	Energy yield (%)	Mass yield (%)	Energy density (kcal/m ³)	CV (kcal /kg)	Energy yield (%)	Mass yield (%)	Energy density (kcal /m ³)
200	4483.1	98.4	97.0	1040771.0	3941.0	98.9	87.0	457867.5
250	5316.7	84.7	70.4	1156372.0	4180.0	84.5	70.4	440121.0
300	6133.5	80.9	58.3	1291726.0	4657.5	75.9	56.5	452135.0

CV: calorific value

product yield and their physico-chemical characterization are shown in Table 2 and 3, respectively. The sawdust (0.6 mm) has shown the maximum yield of 44%, whereas, rice-husk has yielded the least bio-oil among all the pyrolyzed biomass samples. Rice husk, bagasse, pigeon pea and bajra crop residue derived bio-oil could not be tested for its calorific value analysis due to high water content in the bio-oil. Groundnut shells

and sawdust derived bio-oil shown calorific values of 6831.0 kcal/kg and 6329.4 kcal/kg, respectively, due to less water content. Average calorific values of the pyrolysis gas varied from 1791.5-2508 kcal/kg. Viscosity, pH and density of bio-oil were high as compared to other bio-oil. Pyrolysis gas contains H_2 , CO , CH_4 and CO_2 as major gas compounds.

Table 2: Pyrolysis product yields from different agro-residues at 400°C

Biomass / agro residue	Pyrolysis product yield (%)		
	Bio-oil	Bio-char	Pyro-gas
Rice husk	14.0	50.0	36.0
Bagasse (0.6 mm)	32.0	38.5	29.5
Pigeon pea (0.6 mm)	41.0	31.5	27.5
Bajra stalk (0.6 mm)	25.0	40.0	35.0
Groundnut shells (0.6 mm)	40.0	42.0	18.0
Sawdust (0.6 mm)	44.0	40.0	16.0

Table 3: Physico-chemical characterization of bio-oil derived from different agro-residues at 400°C

Agro-residue	Properties of bio-oil				
	CV	Water content (%wt)	pH	Viscosity (cP)	Bulk density (kg/m ³)
Rice husk	N/A	96	4.19	12.17	887.04
Bagasse	N/A	64	4.12	16.82	931.92
Pigeon pea	N/A	86	4.18	78.02	902.70
Bajra stalk	N/A	75	4.15	77.10	888.79
Groundnut shells	6831.0	15	3.90	36.70	1004.0
Sawdust	6329.4	11	3.60	33.0	1007.0

Storage stability and thermal application of bio-oil

Bio-oil collected from sawdust was upgraded with addition of polar solvents. Selection of best suitable solvent and ratio of the solvent was carried out through a simple and quick method by aging of bio-oil at 80 °C followed by phase separation examination. Methanol was found to be the best solvent to stabilize the bio-oil with an optimized solvent to bio-oil ratio of 20% for 23% water content as shown in Fig. 8a. Similarly, for bio-oil containing 10%

water content, iso-propanol has shown best solvent properties with optimized solvent ratio of 10% as shown in Fig. 8b.

Further, investigation on storage stability of the suitable solvent upgraded bio-oil was investigated by measuring the changes in its physical properties by aging at room temperature and 80 °C, respectively. Raw bio-oil stored at room temperature and 80 °C have shown the phase separation within 15 days and 1 day, respectively.

Bio-oil upgraded with addition of 20%

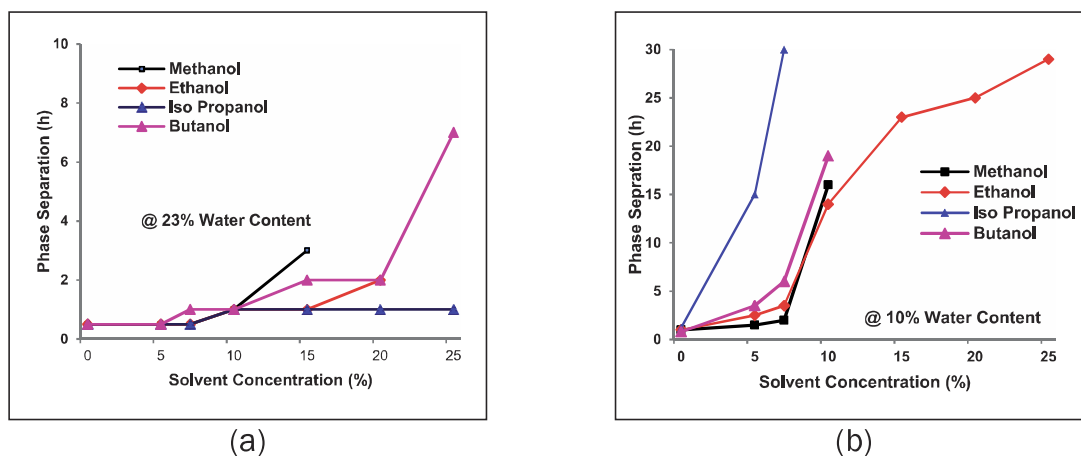


Fig. 8: Effect of different solvents and its concentrations on retardation to phase separation of bio-oil at water content of (a) 23% and (b) 10%

methanol aged at room temperature has the better stability as it does not show any phase separation within 240 days of aging time (Fig. 9a). When it is aged at 80°C, phase separation appeared after 125 days (Fig. 9b). These results show that bio-oil stabilized with methanol can be used for

storage and transportation purpose for its end application. Raw and stabilized bio-oil is demonstrated successfully for thermal application using air blast atomization (paint spray gun) and pressured atomization system (diesel burner).

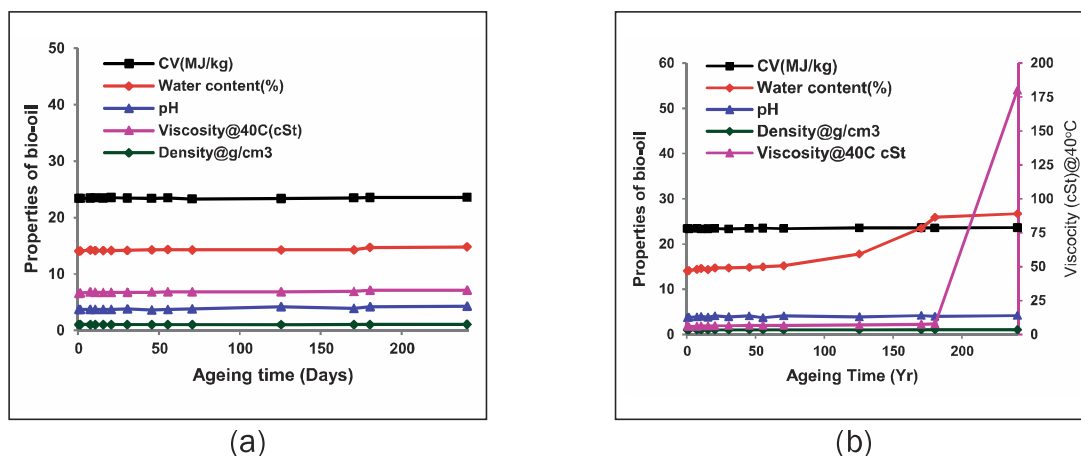


Fig. 9: Changes in physical properties of the bio-oil with aging time for (a) Bio-oil+20% Methanol at room temperature (b) Bio-oil+20% Methanol at 80°C

Continuous-type pyrolysis reactor for production of bio-oil

At SPRERI, a unique vertical moving down bed agitated reactor of 5-10 kg/h was designed, fabricated and demonstrated for continuous production of bio-oil. The reactor was provided with continuous feeding and discharging facility and gas cleaning and cooling system (Fig. 10). Initial trial runs were conducted with sawdust biomass at

400, 450 and 475°C and the results are shown in Table 4. Bio-oil yield was found to be 44, 47 and 53.5% at 400, 450 and 475°C, respectively. Bio-oil yield was improved (5-8%) when compared to lab-scale pyrolysis reactor. Physico-chemical properties of the bio-oil produced at different temperatures are given in Table 5. Further performance evaluation of the reactor with different agro residues is in progress.

Table 4: Trial runs with sawdust biomass at different temperatures

Temperature (°C)	Product yield (%)		
	Bio-oil (%)	Bio-char (%)	Pyro-gas (%)
400±10	44.0	40.0	16.0
450±10	47.0	36.0	17.0
475±10	53.5	28.0	18.5



Fig. 10: Continuous pyrolysis reactor system installed at SPRERI

Table 5: Properties of the bio-oil obtained at different reaction temperature

Properties of the bio-oil	Temperature (°C)		
	400	450	475
CV (kcal/kg)	6401	6520	5971
Water content (%)	10.9	13.4	13.2
pH	3.6	3.5	3.9
Viscosity @ 40 °C (cSt)	30.0	13.7	16.5
Density (g/cm ³)	1.072	1.115	1.140
Solid content (%wt) in bio-oil	1.6	0.91	0.86

Improved biomass cookstove

Forced-draft cookstove with continuous feeding and ash discharge system

Continuous feeding-cum-ash discharge type forced-draft cookstove (Model: 240 FCT-M) has been designed and fabricated (Fig. 11). For continuous feeding, separate stand was provided for vessel support and cookstove was provided with wheels so during the operation, cookstove can be pulled to re-fuel it. A sliding plate was provided at grate

to remove ash during the operation. After fabrication, cookstove was tested at SPRERI as per the BIS standards.



Fig. 11: Forced-draft cookstove (Model: 240 FCT-M) during testing

Table 6 summarizes the results of testing and affirms that the SPRERI designed cookstove has met all the BIS specifications. However, few operational problems have been identified regarding the fan and ash discharge. To counter these problems another cookstove (Model: 240 FCT-M) has been re-designed and developed. Performance testing of the cookstove is under progress.

Table 6: Testing results of forced-draft cookstove (Model: 240 FCT-M) as per BIS specifications

Type of cook-stove	Thermal efficiency (%)	Power rating (kW)	TPM (mg/ MJd)	CO (g/ MJd)	CO:CO ₂ Ratio
As per BIS	≥ 35	≥ 3	≤ 150	≤ 5	≤ 0.02
Forced-draft cookstove	39.67	6.86	139.86	2.78	0.02

Training and Awareness Creation

Training and Demonstrations

Extension division conducted series of twenty (20) one-day awareness programmes on “Various aspects of renewable energy technology” at MGIIRED, Amrol, Dist. Anand. The objective of program was to create awareness among the youth and community about importance and usefulness of renewable energy in the present scenario of energy crisis and climate change.

More than 1000 participants from engineering/polytechnic/ITI colleges and farmers have participated in the training programmes (Table 7). Scientists and technical staff of SPRERI were involved in explaining various technologies such as solar water heating systems, PV integrated solar dryers, solar water pumping system, solar refrigerator, fluidized bed biomass gasifiers, improved biomass cookstoves, liquid bio-fuels (bio-ethanol and microalgae) and bio-methanation technologies to the participants and answered their queries (Fig. 12).

Table 7: Category wise break-up of number of participants of the training programme

Sr. No.	Category	No. of training programmes	Total no. of participants
1	Engineering colleges	13	677
2	Industrial Training Institutes	5	251
3	Farmers/ Women group	2	101

A field visit was also organized for participants to the Technology Park, Renewable Energy Mobile Van and 1 MW solar PV power plant (located at MGIIRED-GEDA centre, Amrol).

The College of Renewable Energy and Environmental Engineering, SDAU, organized one-day training programme on “Importance and implementation of bio-gas plant for



Fig. 12: Views of awareness programme and exposure visit at MGIIRED, Amrol

village prosperity” at Village-Agiya, Ta: Khedbrahma, Dist-Sabarkantha. About 300 farmers from nearby villages and 50 students of College of Renewable Energy and Environmental Engineering, SDAU, attended

the program (Fig.13). Team from SPRERI had attended the programme and delivered a lecture on awareness of the bio-gas and its importance and applications to the farmers.



Fig. 13: Interaction with farmers in the program “Importance and implementation of bio-gas plant for village prosperity” at Agiya, Dist-Sabarkantha

SPRERI scientists also worked as resource personnel in training programmes organized by other organizations

Date	Topic of lecture	Participants/training programme
Human Resource Development Centre, Maharshi Dayanand Saraswati University, Ajmer		
21.08.2017, 24.08.2017 & 25.08.2017	• Use of Renewable Energy in rural domestic sector • Improved biomass cookstoves • Bio-gas plants • Socio-Economic impact analysis of introduction of RE technologies	Group of 40 faculties from various department
Mahatma Gandhi Institute for Integrated Rural Energy Planning & Development, Amrol, Vadodara		
19 – 20, Sep, 2017; 06 – 08, Nov, 2017; 09 – 12, Jan, 2018; 03, Feb, 2018; 06 – 08, Feb, 2018	• Solar technologies • Bio-energy recovery from solid and liquid waste through biological routes • Up-gradation of bio-gas for multiple applications • Thermo-chemical conversion technologies	Students from various colleges

Open House

The 10th Open House was organized at SPRERI on February 15-16, 2018. The purpose was to provide a renewable energy platform for all the farmers, students, faculties and

community to develop understanding and create awareness on different renewable energy technologies under one single umbrella in SPRERI.

Mr. Rohitbhai M Patel, Ex-Minister in Government of Gujarat and leading businessman as chief guest inaugurated the Open House (Fig. 14). He advised the students to have intensive interaction with the scientists and technical personnel of SPRERI and to develop a fairly good understanding about various renewable energy technologies on display. He also advised the youth to try to adopt suitable RE technologies and help fight energy crisis and climate change.

Around 3100 participants, mostly students and their teachers from science, engineering, management and other disciplines belonging to different institutions spread all over Gujarat were participated in the Open House. Visitors included more than 300 farmers from different villages. Scientists and technical staff of SPRERI explained the technologies and systems displayed in the Open House and interacted with participants on one-to-one basis to provide any clarifications to their queries.



Fig. 14: Open House inaugural speech by Mr. Rohitbhai Patel, views of the students being explained SPRERI technologies

Miscellaneous:

Hari Om Ashram Prerit Young Scientist award

Every year SPRERI announces HARI-OM ASHRAM PRERIT YOUNG SCIENTIST/ENGINEER AWARD consisting of Certificate and Cash price ₹ 51,000/- which is sponsored by HARI - OM ASHRAM, Nadiad, commemorating the birth centenary of Pujya Mota for

outstanding research in the field of RE.

During the 10th Open House inaugural session, the Young Scientist award for the period 2013-2016, was conferred to Dr. Preeti Mehta, Scientific Officer, DBT-IOC, Center for Advance Bio-energy Research, IOCL, Faridabad by Mr. Rohitbhai Patel for her outstanding research on “Development of Two Stage Integrated Process for the

Production of High Value Omega-3 Fatty Acids (Mainly DHA) along with Lipids for Bio-diesel using CO₂ as feedstock via Novel Chemoheterotrophic Route” (Fig. 15).



Fig. 15: Hari Om Ashram Prerit Young Scientist award conferred to Dr. Preeti Mehta

Post-graduate Dissertations

Name of the student/degree	Name of the Institute/ University	Topic of research work
Mr. Mitkumar Babubhai Patel (M.Tech)	A. D. Patel Institute of Technology (ADIT), New V.V. Nagar	Modelling and performance evaluation of solar operated agro-produce drying unit

Consultancy

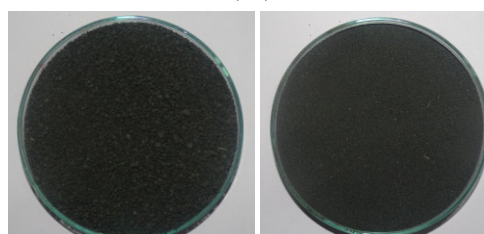
Pre-feasibility study for utilization of textile sludge for thermal application using a fluidized bed gasifier

A textile Mill based at Ahmedabad, generates around 10 tonnes per day (TPD) of textile sludge and dumps it at landfills. In order to dry and utilize it in-house, through gasification route, the mill approached SPRERI for fluidized bed gasification technology and have agreed to send their textile sludge samples for trials and testing. As received, the textile sludge was processed through different physical treatments *i.e.* drying, grinding and sieving and also characterized the physico-chemical properties. Fig. 16 shows the as received textile sludge and after grinding particles are separated into different fractions by sieving. Proximate and ultimate analysis of the raw sludge sample was also done to evaluate its

potential for gasification. Gasification test runs were carried out using particle size below 0.4 mm. Prior to gasification, fluidization properties of the material were studied. Based on the results obtained through preliminary testing, a proposal was submitted for setting up of a 2 TPD gasification system for the utilization of textile sludge.



(a)



(b)

Fig. 16: Images of textile sludge (a) As received sludge samples (size: 27-72 mm lumps; bulk density: 870 kg/m³). (b) Coarse particles (0.4-3 mm) and fine particles (≤ 0.4 mm) after sludge gridding and sieving (bulk density: 837-870 kg/m³)

Memorandum of Understanding (MoU) and Technology Transfer

- Agreement was signed with M/s Steelhacks Industries, Vithal Udyognagar for PV integrated solar low tunnel dryer on August 3, 2017.
- Agreement was signed with M/s Kosol Energie Pvt. Ltd. for PV integrated solar low tunnel dryer on September 15, 2017.
- A MoU has been signed by SPRERI with M/s Urja Bio Systems Private Limited, Pune for the transfer of SPRERI's technology on odourless bio-methanation of fruit and vegetable waste on December 1, 2017.

Technology Demonstrations

DST Core Support Programme

SPRERI team conducted visit to twenty one (21) villages of three (03) districts namely Chotta Udaipur, Anand, and Mahisagar with following objectives:

- To understand the major issues of the rural areas.
- To assess the potential for introducing renewable energy technologies and sensitize community for natural resources and adaption of renewable energy in their daily lives.
- In addition, to collect basic information,

socio-economic and village level data that could help in developing plan for implementing the programme.

The community has shown great interest for renewable energy technologies like solar water pump for irrigation, solar light, solid state bio-gas plant and improved biomass cookstove etc. In Zalasag village of Mahisagar district, 60 households are willing to install solid state bio-gas plants and 200 households are interested in improved biomass cookstoves. In first phase, 25 nos. of 2 m³ capacity solid state bio-gas plant



Fig. 17: Meeting with village community and marking and digging for bio-gas plants

implementation is in progress.

For impact of various cooking fuels and devices on indoor air quality various equipment/instruments are procured and preparation of semi-control testing facilities at SPRERI campus is in progress.

One of the major activities under DST core

support project includes field evaluation, refinement and commercialization of dhabha size improved biomass cookstove. For this, survey was conducted in several dhabhas near highway roads and other prime locations of Anand district. Based on the results of field survey and after detailed discussion with

the dhabha owners about their daily cooking requirement; 7 kW/th capacity forced-draft dhabha size cookstove is selected for design, development and implementation. While designing the basic requirements of dhabha

owners' i.e. continuous ash disposal, safe and easy fuel handling, and portability were given specific importance. After completion of the designing the prototype is fabricated (Model: 240 FCT-M) and testing is under progress.



Fig. 18: View of setting up side feeding improved biomass cookstoves

Rural Development Programme

Demonstration-cum-awareness programmes were organized in fifty-eight (58) villages of eleven (11) districts for renewable energy technologies such as SPRERI-TECH improved biomass cookstove, toilet linked bio-gas plant, solar light, etc. Around 1300 farmers including large number of women participated in the programmes and actively interacted with SPRERI personnel. Many participants registered their names for SPRERI-TECH improved biomass cookstove.

One hundred fifty eight (158) units of SPRERI **side-feeding improved biomass cookstoves** (Model: 190 NDS-L) for continuous operation were fabricated and one unit each was

installed in 158 selected households in fifty-seven (57) villages of ten (10) districts (Fig. 18). All the users were trained by SPRERI personnel for operation and maintenance of the stove through live demonstrations. Around 250 villagers including many women and young girls participated in the programmes and learnt salient features and method of operation and maintenance of the device.

The family size solid-state toilet linked bio-gas plants (4-6 m³/d capacity) were set-up and demonstrated at four (04) selected farmer's sites in four (04) villages of Anand and Kheda districts (Fig. 19). SPRERI provided the technical guidance, trained mason and selected items like inlet pipe, bio-gas



Fig. 19: View of construction of solid state bio-gas plants

burner etc. for the construction. Base data of all these users were collected. The bio-gas at all the sites is being used for thermal applications *i.e.* cooking meals, cooking cattle feed and water heating.

Performance monitoring of four (04) family size toilet linked demonstration bio-gas plants was continued. Field performance data and slurry samples from inlet and outlet were collected. Average TS of the feed and the outlet slurry were found to be in the range of 9.0-15.9% and 6.9-11.8%, respectively. The farmers, in general, reportedly used 40-70% less water than the bio-gas plants of common designs. All farmers were found satisfied with the quality and quantity 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 water heating. Duration of bio-gas use was found to vary from 1-3 h per day depending upon the

number of family members, size of the plant and quantity of the dung fed. The methane contents of the bio-gas samples collected from a few sites was found to be around 58%. Periodic monitoring and back-up support will continue.

Energy Audit

Energy auditing of the rural households in Gujarat and scope for renewable energy for cooking and illumination

To conduct a study, twenty (20) households were selected from Anand and Vadodara districts with average family size of 4-6 people. The data were collected using a questionnaire prepared and the actual measurement on amount of cooking fuel used and time spent in domestic activities were made. In these selected households, it was found that only male members have gained education up to school level, whereas mostly all the women were illiterate. About 90% of

the male members work in agriculture sector. It was observed that almost all the selected households are using “C” type traditional biomass cookstove with high levels of smoke and emissions and have low efficiencies of around 10-12%. All households are mainly using wood/surplus crop residue/dung cake as cooking fuel.

Besides, illuminations in these households are another prominent problem. Since the houses are highly scattered and located in the farm, *i.e.* remain unconnected to grid power due to the high cost of laying the cable which has to be borne by the beneficiary, people use kerosene lamps for illumination in their isolated households. Preliminary energy audits for cooking and illumination have been done and the energy consumption pattern in the household shown that cooking consumes maximum energy up to 72%, followed by the lighting load being 28%. Fuel wood was found to contribute the maximum portion of 67% to meet the energy consumption for cooking application. The energy consumption pattern, based on total number of dependents in any particular family and their living standards, varied for individual households.

Energy audit of groundnut farming in Gujarat

Preliminary energy auditing of groundnut crop has been started. Banaskantha, Junagadh and Amreli districts were selected for energy auditing of the groundnut crop. Initially forty-nine (49) farmers are selected for the audit and the information used in this study is collected from the fields of groundnut in seventeen (17) main villages of the studied region. Data were collected from the farmers

in a face-to-face survey in the 2017-18 production year. The data collection through questionnaire was made with 49 randomly selected groundnut farmers.

Based on the data, the average size of investigated farms was found to be around 60.37 ha. The average size of farm family in the research households was found to be 7 people. The average age of the farmers was in the range of 42-43 yrs and their average experience in agriculture being 18 yrs. Research results demonstrated that 79.59% were having primary school education and 19.48% were university graduates. Groundnut (40.06%), Bajra (24.00%), Green gram (14.83%), Wheat (10.70%), Sesame (8.70%) and Sweet watermelon (1.80%) were the major crops in the research area.

Common varieties of groundnut were hybrid seeds (Axay-37, Gujarat-2, 24, 66, Gurabin-37, Rohini) and were used in the range of 160-190 kg/ha. Most groundnut farms in the Banaskantha region was irrigated by sprinkler, whereas Amreli and Junagadh farms were irrigated through open channel (Fig. 20). Irrigation was observed as the major energy intensive farm operation. The energy use in the irrigation was determined on the basis of fuel consumption *i.e.* L/ha or electricity consumption. Both chemical fertilizers and farmyard manure were used among the surveyed groundnut growers. Weeds were cut by sickle. Thus, the weed control was human energy intensive farm operation. Spraying of pesticides was usually done in August. Harvesting was another human energy intensive farm operation in the research area.



Fig. 20: Weeding and irrigation in groundnut farm

Operation wise average input energy

To assess the energy scenario of the area, average of energy input and outputs of all the villages were taken. The groundnut crop cultivation was divided into different operations and thus operation wise energy was calculated. The energy involved in each operation was further divided into direct energy and indirect energy. Irrigation consumed maximum operation wise direct energy with a value of 9186 MJ/ha (25.70%). In case of indirect energy, fertilizer was maximum energy consuming operation with energy consumption of 8445.28 MJ/ha (23.61%). FYM (farm yard manure) application came next with 3862.95 MJ/ha (10.80%) as indirect energy.

Source wise average input energy

Among different direct sources, fuel energy was used maximum with the

value of 14549.12 MJ/ha (40.69%), whereas in case of indirect energy sources, chemical energy was consumed maximum with the average value of 10840.12 MJ/ha (30.31%).

Improved biomass cookstove with chimney

Preliminary design and development of a top plate arrangement with chimney, suitable for SPRERI-TECH improved biomass cookstove (Model: 160 NDS-F) was carried out. Schematic for cookstove with chimney is shown in Fig. 21. Top plate of the cookstove was designed for double pot (to utilize the heat of the flue gases), followed by chimney which creates a draft to release smoke. Thermal efficiency and burning rate were completed as per BIS standards. Performance data and Indoor air quality data with and without chimney arrangement are summarized in Table 8.

Table 8: Performance of the SPRERI-TECH cookstove without and with chimney

Model/Description		“C” Traditional cookstove	SPRERITECH (160 NDS-F) (% reduction/improvement)	
			without chimney	with top plate and chimney
Burning rate (kg/h)		1.20	1.40	1.05
Thermal efficiency (%)		16.14	28.00 (+42.36%)	26.10 (+38.16%)
Power rating (kW)		0.95	1.94	1.36
PM _{2.5} (mg/m ³)	Avg.	4.45	2.43 (-45.40%)	1.82 (-59.10%)
	Max.	42.00	22.00 (-47.62%)	13.66 (-67.47%)
PM ₁₀ (mg/m ³)	Avg.	4.55	2.54 (-44.17%)	1.92 (-57.80%)
	Max.	42.20	22.90 (-45.73%)	13.79 (-67.32%)
TPM (mg/m ³)	Avg.	4.75	2.81 (-40.84%)	2.14 (-54.95%)
	Max.	42.50	25.25 (-40.59%)	13.94 (-67.20%)

PM: Particulate matter; TPM: total particulate matter

Thermal efficiency was found to be slightly reduced for the cookstove with chimney as compared to without chimney cookstove due to heat losses through the top plate. The temperature is recorded at the chimney outlet (height–7 ft.) in range of 108–115°C. As expected the concentration of PM_{2.5}, PM₁₀ and TPM were found to be the highest for “C” type and lowest in SPRERI-TECH cookstove with chimney.



Fig. 21: Testing of biomass cookstove with chimney arrangement

Patent granted

1. A patent has been granted (Patent No.292125) for “ An odour-free process for handling of organic solid wastes for bio-methanation and simultaneous production of solid bio-fuel/manure” (Application No. 3267/MUM/2012) on January 25, 2018.

Regional Test Centre

Regional Test Centre (RTC) for solar thermal devices was established at SPRERI during 1985. It is supported by Ministry of New and Renewable Energy, Govt. of India. Since 2000, the RTC is performing tests on solar thermal devices, as per procedure prescribed and approved by Bureau of Indian Standard, under BIS Certificate No.7114433. The centre has been accredited by National Accreditation Board for Testing & Calibration Laboratories (NABL) (Cert. No. T-2341) since 2012.

The NABL accreditation is valid till September 11, 2018. On May 8, 2017, a BIS surveillance (surprise) audit was carried out and completed without any non-conformity. Further, BIS renewal audit was conducted during September 14-15, 2017 by a team of BIS auditors. The audit was completed with six minor and one major non-conformities (NCs). All the NCs were addressed satisfactorily and extension of BIS recognition for the RTC was received till August 15, 2020. The NABL

document 218 was prepared and submitted on August 10, 2017 for the NABL desktop surveillance.

A third party inspection for a solar compound parabolic concentrator (CPC) based hot water generation plant installed at M/s Hindustan Unilever Ltd., Silvasa was conducted on July 7, 2017 and inspection report was submitted

to MNRE on August 30, 2017.

RTC also participated in and organized inter-laboratory comparison (ILC) programme for flat plate collector and solar box cooker. Details on number of samples received for testing & nodal ILC programme are mentioned below in Table 9. Test reports issued for the same are also indicated in the Table 9.

Table 9: Statement of devices received and tested during the year

Devices	Received for testing (Units)	Testing completed (Units)*
Solar flat plate collectors		
• BIS	0	1
• Manufacturer	6	1
• ILC	2	0
Solar box cooker		
• BIS	0	0
• Manufacturer	0	0
• ILC	2 (received) 1 (sent)	1
ETC/FPC based solar water heating systems	4	6
Total	15	9

* Includes few devices which were received during the previous year

Human Resource Development

1. Mr. Kailas Trivedi and Er. Samir Vahora participated in training programme on PFMS at National Innovation Foundation – India, Gandhinagar, Gujarat on October 9-10, 2017
2. Er. Velmurugan Balasubramanian participated in a workshop “FCRA roundtable” organized by Navjivan Centre for Development” at New Delhi, November 4, 2017.
3. Dr. Ramkishore Singh and Er. Farha Tinwala participated in training programme “Laboratory quality management system and internal audit as per ISO/IEC–17025 at National Institute of Training in Standardization (NITS), Noida on November 14-17, 2017.

Participation in Meetings, Seminars and Conferences

Sr. No.	Details of the programme	Date and place	Scientist
1	Attended Annual All Regional Test Centres Meeting organized by MNRE at School of Energy Sciences	April 20, 2017 Madurai Kamaraj University, Regional Test Centre, Madurai	Er. Asim Kumar Joshi
2	Participated in the workshop on Financing state climate actions	May 23, 2017 Gandhinagar	Dr. Gaurav Mishra
3	Attended brainstorming session-cum- external project submission meeting for WISIONS-2017, Germany	June 16, 2017, FES, Anand	Er. Asim Kumar Joshi Er. Farha Tinwala
4	Third party inspection of solar CPC based hot water generation plant installed by M/s Thermax, Pune	July 7, 2017 M/s Hindustan Unilever Ltd., Silvasa	Er. Asim Kumar Joshi
5	Quinquennial Review Team (QRT) meeting (2012-17) on ICAR-AICRP on EAAl and ICAR-CRP on EA	July 10-12, 2017 MPUAT, Udaipur	Dr. Gaurav Mishra Er. Velmurugan Balasubramanian Dr. Kiran Kumar Adepu Dr. Jay Pandey Er. Samir Vahora Er. Asim Kumar Joshi
6	Attended a brainstorming meeting as an expert for identification of the problems relevant to the state and their bio-technology solutions for research support to academia: environmental bio-technology	July 14, 2017 GSBTM, Gandhinagar	Dr. Madhuri Narra
7	Discussion on implementation and presentation on SPRERI's bio-methanation technologies on dairy effluent and solid waste generated in milk processing industries for energy recovery	August 1, 2017 Cavin Kare Pvt. Ltd. Kanchipuram	Er. Velmurugan Balasubramanian
8	Participated in the ICAR-IFAD interaction workshop on Integrating renewable energy technologies (RET) for smallholder agriculture in India	August 3, 2017 New Delhi	Dr. Gaurav Mishra
9	Attended meeting for discussion on consultancy for PV plants installation at AMUL and associated dairies	August 4, 2017 AMUL, Anand	Er. Asim Kumar Joshi Er. Farha Tinwala
10	Meeting with officials of Shree Krishna Medical College Hospital regarding recommissioning of kitchen waste bio-gas plant	August 11, 2017 Karamsad	Er. Velmurugan Balasubramanian
11	Delivered a lecture on Use and importance of biomass energy in renewable energy sector at GCET College	August 11, 2017 Vallabh Vidyanagar	Dr. Gaurav Mishra
12	Discussion on implementation and presentation on SPRERI's bio-methanation technologies on dairy effluent and solid waste generated in milk processing industries for energy recovery	August 19, 2017 Vasudhara Dairy Boisar	Er. Velmurugan Balasubramanian
13	Delivered a guest lecture on global energy scenario and environmental concerns	August 21, 2017 Vidya Dairy, Anand	Dr. Madhuri Narra

Sr. No.	Details of the programme	Date and place	Scientist
14	Best oral presentation was awarded for the full length paper entitled Laboratory-scale humic acid extraction plant: a value addition from bio-gas spent slurry at a symposium on sustainability of chemical industries: exploring new avenues for growth	August 22-23, 2017 GCET, Vallabh Vidyanagar	Er. Bipin G. Vyas Ms. Manisha Harijan
15	To discuss and explore possibilities for solar-biogas hybrid based cold storage in dairy sector	September 11, 2017 Mother Dairy Fruit & Vegetable Pvt. Ltd., Mongolpuri and Mother dairy plant, Parpatganj, New Delhi	Er Asim Kumar Joshi
16	Best oral presentations at National conference on Recent advances and future trends in chemical technology-2017 (RAFTCT-2017), Nirma University - Presentation on Lignocellulosic agro-residual waste materials to liquid biofuels - A green technology process - Presentation on Dairy effluent to irrigation water: A holistic bio-remediation process using microalgal treatment	September 16, 2017 Ahmedabad	Mrs. Aesha Patel Mrs. Ekta Shah
17	Participated in the 2 nd India-China technology transfer, collaborative innovation and investment conference 2017	September 19-20, 2017, New Delhi	Dr. Gaurav Mishra
18	Attended RE-Expo	September 21, 2017 Greater Noida	Er. Asim Kumar Joshi
19	Mission Innovation India workshop on sustainable bio-fuel Innovation Challenge, ICgeb	October 9, 2017 New Delhi	Dr. Kiran Kumar Adepu
20	Attended the launch event of the Gujarat results of USAID-Ministry of Power report called, Greening the Grid: Pathways to integrate 175 gigawatts of renewable energy into India's electric grid – Volume II	November 3, 2017 GERC, Gandhinagar	Dr. Gaurav Mishra
21	Participated in brainstorming session on Recent advances in biomass energy research and management. Presentation on Bio-oil production techniques and gaps	November 9, 2017 CIAE, Bhopal	Dr. Gaurav Mishra Dr. Jay Pandey
22	Participated in the 3 rd edition of India industry water conclave and 5 th Edition of FICCI water awards	November 28, 2017 FICCI, New Delhi	Dr. Gaurav Mishra
23	Presented annual progress report of the project Development of an integrated process for co-production of liquid/gaseous bio-fuel from pre-treated lignocellulosic biomass	November 28, 2017 GSBTM, Gandhinagar	Dr. Madhuri Narra
24	Participated in the 7 th state level exhibition and conference on Solar energy devices	December 9, 2017 GCET, Vallabh Vidyanagar	Dr. Gaurav Mishra
25	Attended as Jury members in the 7 th state level exhibition and conference on Solar energy devices entitled India's next development by renewable energy and astronomy	December 9, 2017 G H Patel College of Engineering and Technology, Vallabh Vidyanagar	Dr. Ramkishore Singh Er. Asim Kumar Joshi

Sr. No.	Details of the programme	Date and place	Scientist
26	Attended the workshop on Sustainability of energy systems through smart grid and renewable energy integration	December 12, 2017 Charotar University of Science & Technology, Changa	Dr. Ramkishore Singh Er. Asim Kumar Joshi
27	Oral presentation on Simultaneous saccharification and fermentation of cellulosic residue of corncob for production of bio-ethanol and recovery of a value added by-product from a waste stream was made at 6 th International conference on advances in energy research	December 14-17 2017, IIT, Mumbai	Mrs. Kumud Macwan
28	Project review meeting on consortium research project on Energy from Agriculture-Presentation of progress report	December 18, 2017 SPRERI, V.V. Nagar	Dr. Gaurav Mishra Dr. Kiran Kumar Adepu Dr. Madhuri Narra Dr. Jay Pandey Er. Pradeep Kumar Budde
29	Participated in the workshop on Non-conventional energy sources-biomass and bio-energy and delivered a lecture on Biomass energy: Indian and global status and SPRERI introduction	December 15-16, 2017 Pimpri Chinchwad College of Engineering, Pune	Dr. Gaurav Mishra
30	Participated in the Mission innovation - India stakeholders meet on public-private cooperation for clean energy innovation 2017	December 20, 2017 New Delhi	Dr. Gaurav Mishra
31	Meeting with officials of M/s Mother Dairy Fruit and Vegetable Unit regarding bio-methanation plant	January 3, 2018 New Delhi	Er. Velmurugan Balasubramanian
32	Discussion on implementation and presentation on SPRERI's bio-methanation technologies on dairy effluent and solid waste generated in milk processing industries for energy recovery	January 4, 2018 Ajanta Raaj Proteins Limited, Agra	Er. Velmurugan Balasubramanian
33	Attended the workshops on 52 nd Annual Convention of Indian Society of Agricultural Engineers (ISAE) and National symposium on Doubling farmer's income through technological interventions and hosted stall presenting SPRERI technologies	January 8-10, 2018, FPT-BE, AAU, Anand	Dr. Gaurav Mishra Dr. Jay Pandey Er. Asim Kumar Joshi Er. Farha Tinwala
34	Discussion on implementation of SPRERI's bio-conversion and thermo-chemical conversion technologies in potato processing industry	January 9, 2018 Chheda Specialities Foods Limited, Palghar	Er. Velmurugan Balasubramanian Dr. Madhuri Narra Er. Jignesh Makwana
35	Attended 4 th Information & networking event: EU-India call on water	January 11, 2018 Vadodara	Dr. Madhuri Narra Dr. Ramkishore Singh Er. Asim Kumar Joshi Er. Gaurav Dixit
36	External examiner for student's project evaluation	January 12, 2018 SDAU, Sardarkrushinagar	Dr. Gaurav Mishra

Sr. No.	Details of the programme	Date and place	Scientist
37	21 st Workshop of All India Coordinated Research Project on Energy in Agriculture and Agro-based Industries, ICAR-CIAE, 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 renewable energy systems and Energy management in agriculture activities	January 16-20, 2018 TNAU, Coimbatore	Dr. Gaurav Mishra Dr. Kiran Kumar Adepu Dr. Madhuri Narra Dr. Ramkishore Singh Dr. Jay Pandey Er. Samir Vahora
38	Attended seminar on Accreditation: tool for global acceptance of solar and allied products	January 18, 2018 Electrical Research and Development Association, Vadodara	Er. Asim Kumar Joshi Er. Jigar Andharia
39	Visited solar-bio-gas hybrid refrigeration system and explained the working principle and need of the system and other SPRERI solar based technologies at SPRERI with the expert from NDDB, Dr. Omveer Singh MD, Dairy Services	January 19, 2018, AAU site, Anand	Er. .Velmurugan Balasubramanian Er. Asim Kumar Joshi Er. Farha Tinwala
40	Attended 7 th National conclave for laboratories under QCI and NABL	January 23-24, 2018 Ahmedabad	Er. Asim Kumar Joshi Er. Farha Tinwala
41	Discussion on implementation and presentation on SPRERI's bio-methanation technologies on dairy effluent and solid waste generated in milk processing industries for energy recovery	February 5, 2018 Thiruvananthapuram Dairy, Ambalathara	Er. Velmurugan Balasubramanian
42	Presentations on submitted R&D and demonstration project proposals	February 5, 2018 GEDA, Gandhinagar	Er. Samir Vahora Er. Jignesh Makwana Er. Farha Tinwala
43	Oral presentation was made to the UGC-National Conference on Current trends in Biological sciences on Bio-gas production from non-detoxified corn cob acid hydrolysate using anaerobic hybrid reactors: a potential carbon source	February 9, 2018, Vallabh Vidyanagar	Dr. Anil Prajapati
44	12 th Social innovation technical advisory group (STAG) meeting	February 16, 2018, New Delhi	Dr. Kiran Kumar Adepu
45	Participated in Roundtables and plenary sessions on Solar energy: energy of tomorrow's India organized by Institute Français en Inde and UPES under the framework of Bonjour India	February 16-17, 2018, University of Petroleum and Energy Studies, Dehradun	Dr. Ramkishore Singh
46	Attended All India Seminar on Recent trends in renewable energy application & research and delivered a lecture on Prospects in bio-energy in India	February 17, 2018 Ahmedabad	Dr. Gaurav Mishra
47	Attended 18 th meeting of renewable energy sectional committee, MED 04 in joint session with 11 th meeting of Solar thermal energy Subcommittee, MED 04:1	February 21, 2018, Manak Bhawan, BIS, New Delhi	Dr. Ramkishore Singh
48	Visited user site for solar low tunnel dryer testing and troubleshooting	February 21-23, 2018, Akanksha Masala Mathri Kendra, Lucknow	Er. Asim Kumar Joshi
49	Visited PV panel manufacturing plant of M/s Kosol Energies Ltd.,	February 26, 2018 Ahmedabad	Dr. Gaurav Mishra Dr. Ramkishore Singh Er. Asim Kumar Joshi

Sr. No.	Details of the programme	Date and place	Scientist
50	Attended an International conference on sustainable bio-fuels	February 26-27, 2018, New Delhi	Dr. Madhuri Narra
51	EU-India conference on Advanced bio-fuels, Ministry of Petroleum and Natural Gas	March 7-8, 2018 New Delhi	Dr. Kiran Kumar Adepu
52	International symposium on Water resources challenges and sustainability (WRCS), IIT Indore – Presentation on A novel and cost-effective green process for conversion of dairy wastewater into potable water	March 10, 2018 Indore	Dr. Shaishav Sharma
53	Participated in the Knowledge summit – first high-level Indo-French summit on higher education and research with the participation of the Confederation of Indian Industry and the Ministry of Science and Technology on the occasion of the first state visit of French President Emmanuel Macron to India	March 10-11, 2018 New Delhi	Dr. Gaurav Mishra
54	Attended the 5 th H.M. Patel Memorial lecture delivered by Shri Nitin Desai on Water and welfare	March 13, 2018 AERC, Vallabh Vidyanagar	Dr. Gaurav Mishra Er. Samir Vahora
55	Annual review workshop of consortium research project on Energy from Agriculture-Presentation of annual progress report of SPRERI centre	March 20, 2018 New Delhi	Dr. Gaurav Mishra Dr. Kiran Kumar Adepu Dr. Madhuri Narra Er. Pradeep Kumar Budde
56	Meeting with officials of M/s Vidya Dairy regarding dairy effluent based bio-methanation plant	March 20, 2018 Anand	Er. Velmurugan Balasubramanian

Papers Published

1. Sampath Kumar Gundu, Asim Kumar Joshi, Gokul Raj Arthanari, Samir Vahora, Mukul Dubey and Murari Shyam, 2017. Performance evaluation of solar–bio-gas hybrid cold storage system for transient storage of horticultural produce. Springer proceedings in energy-concentrated solar thermal energy technologies: recent trends and applications, 211-216.
2. Gokul Raj Arthanari, Arun Bollavarapu, Mukul Dubey, 2017. Development of dual-axis tracking control system for Scheffler dish concentrator. Springer proceedings in energy-concentrated solar thermal energy technologies: recent trends and applications, 23-29.
3. Madhuri Narra, Jyoti Divecha, Disha Shah, Velmurugan Balasubramanian, Bipin Vyas, Manisha Harijan, Kumud Macwan, 2017. Cellulase production, simultaneous saccharification and fermentation in a single vessel: A new approach for production of bio-ethanol from mild alkali pre-treated water hyacinth. Journal of Environmental Chemical Engineering, 5: 2176-2181.
4. Aesha Patel, Ekta Shah, Shaishav Sharma, Gaurav Dixit, Kiran Kumar Adepu, 2017. Lignocellulosic agroresidual waste materials to liquid bio-fuels-A green technology process. International Journal of Research, 4: 843-849.
5. Ekta Shah, Aesha Patel, Shaishav Sharma, Gaurav Dixit, Kiran Kumar Adepu, 2017. Dairy effluent to irrigation water: A holistic bio-remediation process using microalgal treatment. International Journal of Research, 4: 895-902. (Awarded as best paper)
6. Velmurugan Balasubramanian Madhuri Narra, Bipin Vyas, Samir Vahora, Dipak R Shah, Ajay

- Zala, Bhavesh Patel, 2017. Bio-gas from dairy scum- A case study of Vidya Dairy. Indian Dairyman, 44-47.
7. Patel H, Kumar AK, Shah A, 2017. Purification and characterization of bi-functional GH3 family b-xylosidase/b-glucosidase from *Aspergillus niger* ADH-11. International Journal of Biological Macromolecules, 109: 1260-1269.
 8. Kiran Kumar Adepu, Shaishav Sharma, 2017. Recent updates on different methods of pretreatment of lignocellulosic feedstocks - A review. Bioresources and Bioprocessing, 4: 1-7.
 9. Prakash Chandra Jena, Murari Shyam, Asim Kumar Joshi, 2018. Tar and particulate matters removal from producer gas by using oily organic filter media. International Journal of Agriculture, Environment and Biotechnology, IJAEB: 11: 39-44.
 10. Kiran Kumar Adepu, Ekta Shah, Aesha Patel, Shaishav Sharma, 2018. Process evaluation of cellulosic ethanol production from natural deep eutectic solvent pre-treated rice straw: solvent recovery and its reuse. Journal of Molecular Liquids, 260: 313-322.
 11. Madhuri Narra, Kumud Macwan, Bipin Vyas, Manisha Harijan, Disha Shah, Velmurugan Balasubramanian, Anil Prajapati, 2018. A bio-refinery concept for production of bio-methane and bio-ethanol from nitric acid pre-treated corncob and recovery of a high value fuel from a waste stream. Renewable Energy, 127: 1-10.

Research Projects Pursued

Solar Energy

“Efficiency enhancement of Scheffler dish solar concentrating technology” (SERI-DST), Investigators: Arun Bollavarapu, Asim Kumar Joshi, Mukul Dubey and Gokul Raj Arthanari (SP-2013- ST-37)

“Regional Test Centre for Solar Thermal Devices” (MNRE), Investigators: Asim Kumar Joshi, Farha Tinwala and Jigar Andharia

“Development of solar air heater integrated with PV panel for combined thermal and electrical applications” (AICRP-EAAI), Investigators: Farha Tinwala and Sampath Kumar Gundu (SP-2017-ST-42)

“Efficiency enhancement of solar thermal collectors by using nanofluids” (AICRP-EAAI), Investigators: Farha Tinwala and Mukul Dubey (SP-2017-ST-43)

Bio-Conversion

“Techno-economic evaluation of SPRERI cellulosic ethanol technology using selected crop residues and development of scale-up system” (ICAR-CRP on EA), Investigators: Madhuri Narra, Velmurugan Balasubramanian and Kiran Kumar Adepu (SP-2015-AT-56)

“Development of a cost effective green technology for pilot-scale production of cellulosic ethanol from

lignocellulosic biomass using natural deep eutectic solvents” (ICAR-CRP on EA), Investigator: Kiran Kumar Adepu (SP-2015-AT-57)

“Development of a cost-effective green technology for lignocellulosic biomass pre-treatment using natural deep eutectic solvents” (DBT), Investigators: Kiran Kumar Adepu and Pradeep Budde Kumar (SP-2015-AT-59)

“Development of an integrated process for co-production of liquid/gaseous bio-fuel from pre-treated lignocellulosic biomass” (GSBTM), Investigators: Madhuri Narra and Velmurugan Balasubramanian (SP-2016-AT-60)

“Anaerobic digestion of combined alkaline and enzymatically pre-treated crop residue hydrolysate for methane production in a thermophilic high rate reactor” (AICRP-EAAI), Investigators: Madhuri Narra and Velmurugan Balasubramanian (SP-2017-AT-61)

“Demonstration plant for bio-methanation of potato waste from a selected potato processing industry” (AICRP-EAAI), Investigators: Velmurugan Balasubramanian and Madhuri Narra (SP-2017-AT-62)

“Development and evaluation of a continuous stirred tank reactor (CSTR) for enhanced bio-gas production

from pre-treated dairy effluent scum” (AICRP-EAAI), Investigators: Velmurugan Balasubramanian and Madhuri Narra (SP-2017-AT-63)

“Development of a cost-effective pilot-scale microalgal post-harvesting technology” (AICRP-EAAI), Investigator: Kiran Kumar Adepu (SP-2017-AT-64)

“Refinement and demonstration of an integrated process technology for conversion of crop residues into ethanol for use as transport fuels” (DBT), Investigators: Madhuri Narra, Velmurugan Balasubramanian and Kiran Kumar Adepu (SP-2017-AT-65)

“Design and development of pilot-scale cultivation and harvesting of oleaginous microalgae from west coast of India for bio-diesel production” (DBT), Investigators: Kiran Kumar Adepu, Velmurugan Balasubramanian and Mahendra Perumal (SP-2017-AT-66)

Thermo-Chemical Conversion

“Processing, storage and utilization of liquid bio-fuel produced from selected crop residues” (ICAR-CRP-EA), Investigators: Pradeep Kumar Budde and Jay Pandey (SP-2015-PG-62)

“Fluidized bed gasification of torrefied bio-fuel for production of producer gas and analyzing its suitability for thermal and power applications” (AICRP-EAAI), Investigators: Jignesh Makwana and Jay Pandey (SP-2017-PG-63)

“Development of a continuous feeding cum ash discharge type forced-draft biomass cookstove suitable for mix wood blocks and biomass pellets”

Investigators: Jignesh Makwana and Jay Pandey (SP-2017-PG-64)

“Investigating potential of different biomass feedstocks to produce organic-phase rich bio-oil and their physico-chemical characterization” (AICRP-EAAI), Investigators: Pradeep Kumar Budde and Jay Pandey (SP-2017-PG-65)

“Design, development and evaluation of the continuous pyrolysis reactor system for production of bio-oil from agro-residues” (ICAR-CRP on EA) Investigators: Pradeep Kumar Budde and Jay Pandey (SP-2017-PG-66)

Technology Transfer

“DST Core Support Project” (DST, GoI) Investigator: Samir Vahora, Ashutosh Negi, Shweta Verma and Kamal Trivedi (SP-2017-TT-13)

“ORP on the solar tunnel dryer (walk-in type) for drying of fruits and vegetables in agro-industry” (AICRP-EAAI), Investigators: Samir Vahora, Kamal Trivedi and Ashutosh Negi (SP-2017-TT-14)

“Revamping/revival of old defunct KVIC bio-gas plants with modification to low cost fixed dome plant in Gujarat State” (AICRP-EAAI), Investigators: Samir Vahora and Kalu Kachchhava (SP-2017-TT-15)

“Energy audit of cotton and groundnut farming in Gujarat” (AICRP-EAAI), Investigators: Samir Vahora, Ashutosh Negi and Kalu Kachchhava (SP-2017-EM-4)

“Rural Development Programmes” (GoG), Investigator: Samir Vahora (SP-2017-RD-1)

Visitors to SPRERI

1. Shri B.R. Singh, Director, Atmos Power Pvt. Ltd., Ahmedabad and Shri Gaurav Kedia, Chairman, Indian Biogas Association, Gurgaon visited SPRERI on April 29, 2017.
2. Dr. Sateesh Daggupati, Dr. Sachchit Maji and Shri Sukumar Mandal from Reliance Industries Limited, Jamnagar visited SPRERI on May 10, 2017.
3. Prof. M. Natarajan, Asstt. Professor (Sr) and Lab-in-Charge and Dr. T. Srinivas, Professor, CO₂ Research & Green Technologies Centre from VIT University, Vellore visited SPRERI on June 1, 2017.
4. Shri Odhavji Sardhara, Civil Engineer & Contractor and his team from Zenith Construction, Surat visited SPRERI on August 21, 2017.
5. Shri Alay Parikh and Shri Abhishek Poduri from Tata Trust visited SPRERI on September 5, 2017.
6. Shri Atul Shroff, Managing Director from Transpek Industry Ltd., Vadodara visited SPRERI on September 9, 2017.
7. Shri Ashok Chheda, Chairman & Managing Director from Chheda Specialities Foods Pvt. Ltd., Mumbai visited SPRERI on October 9, 2017.
8. Ms. Rakhee Gupta, Director from Transchem Agritech Pvt. Ltd., Vadodara visited SPRERI on October 10, 2017.
9. Shri Rajesh V. Dave, DGM-NABARD and In-charge, Programme Management Unit (PMU), Indo-German Watershed Development Programme (IGWDP), Dahod visited SPRERI on October 18, 2017.
10. Shri Kalpesh Kalthia, Managing Director from Kosol Energies, Ahmedabad visited SPRERI on October 31, 2017.
11. Dr. A.K. Dubey, Principal Scientist and LC-PC CRP on EA from CIAE, Bhopal visited SPRERI during December 18-19, 2017.
12. Shri Abhijit Singh, Engineer from Techno Industries Marketing, Dehradun (Uttarakhand) visited SPRERI on December 20, 2017.
13. Shri Sunil Dhruv and Shri Prayagraj Dhruv from CAD Solution, Vadodara visited SPRERI on January 6, 2018.
14. Dr. Omveer Singh, Managing Director, NDDB Dairy Services, New Delhi visited SPRERI on January 19, 2018.
15. Smt. S. Chhakchhuak, Director, Gujarat Energy Development Agency, Gandhinagar visited SPRERI on February 3, 2018.
16. Shri M.L. Rajvanshi, IFS, CF (Wildlife) and Shri R. Anand, IFS (DCF), Wildlife from Haryana visited SPRERI on February 20, 2018.
17. Prof. Dhaval Pujara, Dr. S.C. Vora and Dr. Urmil Dave from Nirma University, Ahmedabad visited SPRERI on March 6, 2018.
18. Dr. Pratik N. Sheth, Assistant Professor, BITS, Pilani visited SPRERI on March 27, 2018.

SPRERI Team

Director

Dr. Gaurav Mishra

Scientists

Solar Energy Division

Dr. Ramkishore Singh, I/C Head (w.e.f. 21.9.2017)

Er. Asim Kumar Joshi, I/C Head (upto 20.9.2017)

Er. Sampath Kumar Gundu (upto 12.5.2017)

Er. Farha Tinwala

Er. Arun Bollavarappu

Er. Jigar Andharia (w.e.f. 1.5.2017)

Bio-Conversion Technology Division

Er. Velmurugan Balasubramanian, I/C Head

Dr. Kiran Kumar Adepu

Dr. Madhuri Narra

Dr. Anil Prajapati

Er. Bipin G. Vyas (upto 30.10.2017)

Dr. Shaishav Sharma

Er. Gaurav Dixit

Mrs. Kumud Macwan

Ms. Deepti Davla (w.e.f. 19.2.2018)

Ms. Nivedita Iyer (w.e.f. 21.2.2018)

Mrs. Ekta V. Shah

Ms. Manisha Harijan

Mrs. Aesha D. Patel

Thermo-Chemical Conversion Division

Dr. Jay Pandey, I/C Head (upto 31.1.2018)

Er. Pradeep Kumar Budde, I/C Head (w.e.f. 6.2.2018)

Er. Jignesh Makwana

Technology Transfer Division

Er. Samir Vahora, I/C Head

Er. Dinesh Rangapara (upto 4.9.2017)

Er. Kamalchandra Trivedi (w.e.f. 21.2.2018)

Er. Ashutosh Negi (w.e.f. 1.8.2017)

Mrs. Shweta Verma (w.e.f. 8.8.2018)

Er. Kalu Kachchhava

Administration

Mr. Amar Babu Paleti (upto 30.9.2017)

Mr. Kailas Trivedi

Ms. Pragna Dave

Mr. Hitesh Dalwadi

Mr. Harshad R. Suthar

Mrs. Aida Mascarenhas

Mr. Hasmukh Vaghela

Mr. Shaivel Dalwadi

Technicians and Drivers

Mr. Jayesh Parmar

Mr. Bhupendra Prajapati

Mr. Dahya Harijan

Mr. Ramesh Bhoi

Mr. Rajesh Machhi

Mr. Minesh Suthar

Mr. Mahendra Padhiyar

Lab Attendant and Helpers

Mr. Parsottam Harijan

Mr. Ashok Harijan

Mr. Prakash Machhi

Mr. Bhupat Parmar

Mr. Ishwar Harijan

Mr. Harman Parmar

Mr. Ashok Patel

Mrs. Manjula Vadhel

Mr. Shailesh Solanki

Mr. Mukesh Jadav

Mr. Ashok Mochi

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE - VALLABH VIDYANAGAR
BALANCE SHEET AS ON - 31 - 03 - 2018

FUNDS & LIABILITIES	2017	2018	ASSETS	2017	2018
CAPITAL FUND			FIXED ASSETS		
As per last year	1082669.20	1082669.20	1. Furniture & Fixtures	249808.62	249808.62
PROJECT FUND			2. Electric Fittings	151987.85	162350.85
			Add : During the year	10363.00	0.00
Balance from last year (-)	1444241.37	6243647.69	162350.85	162350.85	162350.85
Add / Less during the year (-)	7687889.06	5205469.94	3. Mobile Phone	19600.00	19600.00
(Annexure - A) * (-)	6243647.69	11449117.63	4. Institute Equip.(R & D / Others)	1071372.00	1071372.00
EAR MARKED FUND			5. Jeep GJ-23A-5102	747273.00	0.00
1. Building Fund Provision	3364376.00		6. Car GJ-23 AF 0282	585597.00	585597.00
Add : During the year	0.00		7. New Jeep - 488	0.00	834000.00
	3364376.00	3364376.00	2836001.47	2922728.47	
2. Depreciation Investment Fund	455244.00	455244.00	INVESTMENT		
3. R & D Fund (As per last year)	6817459.73	6934138.73	1. Fixed Deposit	12471265.00	21000000.00
Add : During the year	116679.00	338400.00	2. Deposit in LIC - Graduity Scheme	5911719.63	6654387.55
Less : During the year (Anne - D)	6934138.73	7272538.73	18382984.63	27654387.55	
DONATION			LOANS & ADVANCES		
Balance from last year	1129001.00	1184001.00	1. Tax Deduction at Source	467099.50	712932.46
Add : During the year	55000.00	50000.00	2. Telephone Deposit	20313.00	20313.00
	1184001.00	1234001.00	3. CGM Deposit (Oil Diesel & Petrol)	12400.00	12400.00
PROJECT EQUIPMENT			4. Indian Oxyzen Ltd., Deposit	4252.94	4252.94
Depreciated value of Equip. from last year	81884821.35	89437718.35	5. Mobile Phone Deposit	4680.00	4680.00
Add : During the year	7552897.00	8932848.00	6. Broad Band Security Deposit	3000.00	3000.00
Less : Depreciation Annex. C1	89437718.35	98370566.35	7. Gas Cylinder Deposit	10350.00	10350.00
DEPRECIATION FUND			8. Security Deposit (GEB - New DP)	100920.00	100920.00
As per Block - Annexure - B	6252954.30	5785898.30	9. Loan to Staff & Advance to Project	777870.00	729642.00
LIABILITIES			10. Intrest Accrued	189193.08	422746.66
1. Contingent Development Fund	133400.00	133400.00	1590078.52	2021237.06	
2. Graduity Fund	5911719.63	6654387.55	BALANCE :		
3. Endowment Fund -	1343499.75	1399979.75	Bank Balance	11240298.65	7639871.51
Add : During the year	56480.00	70000.00	Cash Balance	35434.00	179994.00
Annexure - E	1399979.75	1413979.75	11275732.65	7819865.51	
4. Staff Welfare Fund	139659.50	184155.50			
5. Share & Care Fund	152835.00	152835.00			
6. Quiz Programme Fund	58262.00	58262.00			
7. Maintenance Fund (Core Grant)	519179.00	547179.00			
Income & Expenditure A/C					
SURPLUS / LOSS					
From Last/current Yr Balance Sheet	206465.58	252731.47			
Add / Less During the year-17-18		377443.46			
TOTAL					
Add - during the year - 2016-17	46265.89				
TOTAL	252731.47	630174.93			
TOTAL	34084797.27	40418218.59	TOTAL	34084797.27	40418218.59

[Signature]
Accounts Officer
Sardar Patel Renewable
Energy Research Institute

[Signature]
Director
Sardar Patel Renewable
Energy Research Institute

[Signature]
B. C. PATEL & CO.
Chartered Accountants
Mem.No. 32231



Abbreviations

AHR	- Anaerobic Hybrid Reactor	kcal	- kilocalories
AICRP	- All India Coordinated Research Project	kg	- Kilogram
Avg.	- Average	KVK	- Krishi Vigyan Kendra
BGP	- Bio-gas plant	kW	- Kilowatt
BIS	- Bureau of Indian Standards	L	- Litres
CFA	- Central Financial Assistant	LPG	- Liquefied Petroleum Gas
CFD	- Computational Fluid Dynamics	m ³	- Cubic meter
CIAE	- Central Institute of Agricultural Engineering	mg	- Milligram
COD	- Chemical oxygen demand	min	- Minutes
cP	- Centipoise	MJ	- Mega joule
CPC	- Compound Parabolic Concentrator	mL	- Milli Liter
CRP	- Consortium Research Platform	mm	- Millimeter
cST	- Centi Stroke	MNRE	- Ministry of New and Renewable Energy
CV	- Calorific value	MoU	- Memorandum of Understanding
d	- Day	NABL	- National Accreditation Board for Testing and Calibration Laboratories
DBT	- Department of Biotechnology	NADES	- Natural Deep Eutectic Solvents
DHA	- Docahexanoic acid	ND	- Natural draft
DST	- Department of Science and Technology	ORP	- Operational research project
EAAI	- Energy in Agriculture and Agro-based Industries	PAU	- Punjab Agricultural University
EtBr	- Ethidium Bromide	PPP	- Public private partnership
ETC	- Evacuated Tube Collector	PVC	- Polyvinyl Chloride
FD	- Forced draft	Qty	- Quantity
FPC	- Flat-Plate Collection	R&D	- Research and development
FPU	- Filter Paper Unit	RE	- Renewable Energy
g	- Gram	RET	- Renewable Energy Technology
GEDA	- Gujarat Energy Development Agency	RTC	- Regional Test Center
GoG	- Government of Gujarat	SDAU	- Sardar Krushinagar Dantiwada Agricultural University
Gol	- Government of India	SPM	- Suspended particulate matter
GSBTM	- Gujarat State Biotechnology Mission	SPRERI	- Sardar Patel Renewable Energy Research Institute
GUJCOST	- Gujarat Council of Science and Technology	SS	- Stainless steel
h	- Hour	TPD	- Tonnes per day
ha	- Hectar	TPM	- Total particulate matter
HMI	- Human-machine interface	TS	- Total Solids
HRT	- Hydraulic Retention Time	TSC	- Total solid concentration
IBCS	- Improved biomass cook stove	UV	- Ultra-Violet
ICAR	- Indian Council of Agricultural Research	VS	- Volatile solids
IOCL	- Indian Oil Corporation Limited		



Contact for further information:

Ms. Pragna B. Dave

Sr. PA to Director

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