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2016-17

SPRERI
Striving for Excellence

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE

Contents

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(As on 31st March 2017)

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- Gujarat Council of Science and Technology (GUJCOST), Gandhinagar
- Navajbai Ratan Tata Trust, Mumbai
- 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 cook stoves (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 : PV Integrated solar tunnel dryer at SPRERI for drying agricultural produce

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 (RE) research institution and is recognized for post graduate research by many other 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

SPRERI, a leading organization for research and development of renewable energy (RE) technologies, focuses on sustainable biomass conversion and solar energy based solutions, which are technically efficient, economically viable, environment friendly and which 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 RE technologies
- To provide knowledge based insights to influence policies and programmes of the governments for utilization of biomass and solar energy technologies for meeting energy requirements
- To provide specialized training in RE technologies to engineers and scientists and guidance and facilities to research students
- To provide extension support and consultancy to RE programmes
- To test and evaluate RE technologies

Highlights of the Year

The last two decades have seen an increase in access to electricity in India, but still around 240 million people rely on other non-renewable resources. This has an impact on greenhouse gas emissions and is creating drastic changes to our climate system. Keeping this in view, with the new drive by the Government of India after ratifying the Paris Convention on Climate Change in the form of reduction of emission intensity targets, the country is shifting more aggressively towards renewable energy. In numbers, by 2025 India will need a 175 GW-power production capacity from non-fossil fuels. To meet this, research and development in renewable energy will play an important role in achieving the targets.

SPRERI continues its research and development in renewable energy technologies. One of the important projects it has been working on is microalgae cultivation and harvesting to bio-remediate dairy effluent stream and exploring the conversion of microalgae to bio-diesel. Technoeconomic evaluation of different systems *i.e.*, raceway pond, flat-plate bio-reactor and V-shape bio-reactor are under progress to arrive to an efficient & commercially accepted technology.

A demonstration plant for bio-methanation of 500 kg/d dairy effluent scum has been commissioned and is running successfully from more than a year and is able to replace around 10 m^3 of PNG or more than 6 kg of LPG on a daily basis.

In thermo-chemical conversion division, the main focus being on biomass torrefaction and pyrolysis, a 10 kg/h biomass torrefaction and pyrolysis system is under fabrication with support from NRTT (Navajbai Ratan Tata Trust). The natural-draft improved biomass cook stove was further improved on its performance, whereas, based on the market survey and field requirements, (5-7 kW capacity) of development of a forced-draft cook stove was initiated to meet the cooking needs of road-side dhabas.

On extensive testing of a solar-bio-gas based hybrid refrigeration facility of 5 TR for transient storage of horticulture produce, a comparative techno-economic analysis has been made with all available technologies. The payback period for the system (with assumptions discussed in the report) is 10.5 years. While, with the similar assumptions, the payback period for a 60 TR refrigeration facility is estimated to be less than 1 year.

The MNRE supported, BIS approved and NABL accredited Regional Test Center at SPRERI completed testing of 15 solar thermal devices during the year as per BIS/MNRE procedure. The devices tested included 5 flat-plate collectors based water heaters, 8 evacuated tube collector based solar water heaters and 2 solar box cookers.

SPRERI has conducted various training programmes throughout the year.

The annual event "Open House" was organized at SPRERI on February 15-16, 2017. More than 2800 people, primarily under-graduate and post-graduate students and faculty of engineering, management and science colleges from all over Gujarat were participated.

Solar Energy

Solar-bio-gas hybrid cold storage for horticultural produce

The system was tested during the winter for storage of green chilli and cucumber, during the rainy season for storage of unripe banana and during the summer for storage of ripen (kesar) and unripen (desi) mango. The storage and ambient conditions with observed extended shelf life is shown in Table 1. Images of the tested produce are shown in Fig. 1.

Techno-economic feasibility

Cost economics of the developed technology was worked out. The capital expenditure (CapEx) was calculated based on the current pricing of the equipment and accessories while the operational expenditure (OpEx) was calculated based on the energy demand and supply from each energy source and the consumables required thereof. The OpEx also included the annual maintenance and manpower required. Overall cost economics of the system is given in Table 2.

Table 1: Storage conditions and the shelf life of produce stored in different seasons

Season	Produce	Storage conditions				Shelf life (Days)		Improvement in shelf life (%)
		Ambient		Cold room		Ambient	Cold room	
		Temp (°C)	RH (%)	Temp (°C)	RH (%)			
Winter	Green chilli	23 ± 2.0	45 ± 5.0	15 ± 2	90 ± 5	3	10	233
	Cucumber	23 ± 2.0	45 ± 5.0	15 ± 2	90 ± 5	3	9	200
Rainy	Unripen banana	27 ± 1.5	54 ± 1.5	14 ± 1	93 ± 3	9	24	167
Summer	Unripen mango	34 ± 1.0	46 ± 5.0	14 ± 1	93 ± 3	5	21	320
	Ripen mango	34 ± 1.0	46 ± 5.0	14 ± 1	93 ± 3	7	16	129

Table 2: Cost economics of the system

Items	Cost, Rs. (Lakhs)
Capital expenditure based on the current market price (VAM with accessories, solar thermal field, PV plant, bio-gas plant, burner, shed, PNG and necessary cabling and fittings, battery)	59.0
Total annual operational expenditure	5.25
Total	**64.25**

Calculations for payback period include depreciation, market inflation and interest on CapEx. The storage cost/batch was calculated both without subsidy and with 15 % MNRE subsidy. Further, the cost benefit and payback period was calculated by assuming earnings through rentals with profit margins of Rs. 0.75/kg/batch. The assumptions made to determine payback period are given in Table 3. The sample storage cost and payback data is given in Table 4 & 5.

Table 3: Assumptions made to determine payback period

Paramater	Assumed value
System life (years)	20
No. of batches/year	48
Batch duration (days)	7
Batch size (tonnes of unripe mangoes)	9
Interest on loan (%)	12
Annual inflation in operation O & M (%)	5
Annual increment in revenue (%)	5
Loan taken (for % of total CapEx)	70
Loan repayment period (years)	10
Salvage (junk) value (%)	10
Tax benefits on depreciation cost and interest (%)	30

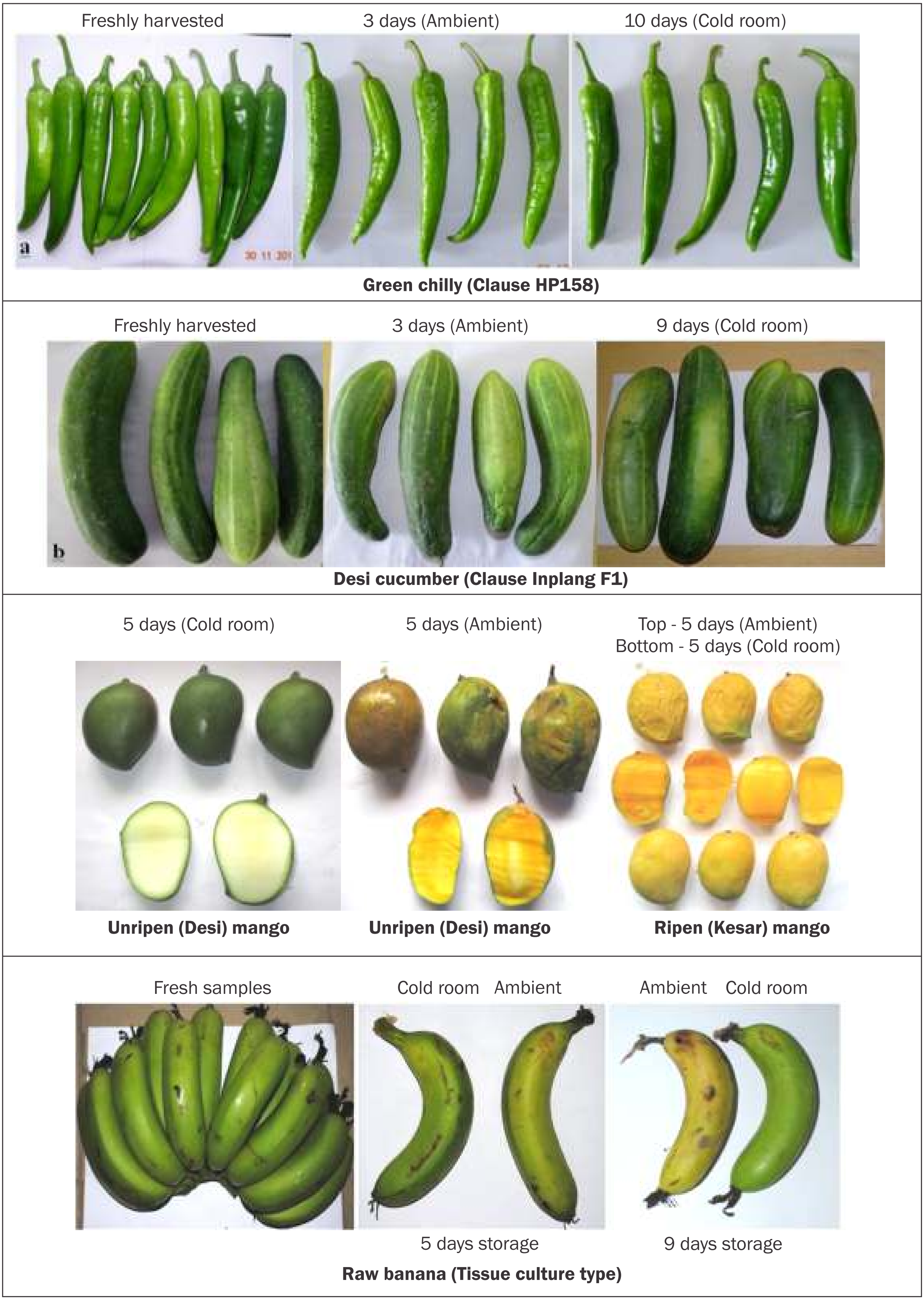


Fig. 1: Images of different horticultural produce before and after storage (at ambient and cold room conditions)

The payback period by assuming a profit margin Rs. 0.75/kg/batch was found to be 11.5 and 10.5 years without and with subsidy respectively, which is nearly 8.5% reduction as compared to without subsidy.

Table 4: Without subsidy (in Rs.)

Total annual Cost (CapEx + OpEx)	6,88,032
Storage cost/kg/batch	1.59
Payback [Profit Rs. 0.75/kg/batch]	11.5 (in years)

Table 5: With 15% MNRE subsidy (in Rs.)

Total annual Cost (CapEx + OpEx)	6,43,782
Storage cost/kg/batch	1.49
Payback [Profit Rs. 0.75/kg/batch]	10.5 (in years)

The system with bio-gas as thermal support and grid as electricity source yielded the least payback period of 8.5 years at a profit margin of Rs. 0.75/kg/batch. Our comparison with the commercial compression based systems operated on grid alone and the compression cycle systems operated by PV only with battery backup was also compared. The results indicate that the grid alone compression cycle system with electricity cost Rs. 7.0/kWh could be the most attractive choice in terms of payback period. The payback period for grid alone system was found to be 1.5 years compared to 8.5, 9.5, 11.5 and 9.5 years for bio-gas + grid, bio-gas + PV, solar thermal + bio-gas + PV, and PV alone, respectively.

In order to scale-up the refrigeration system to 60 TR, calculations were made for bio-gas + grid. The CapEx and OpEx for 60 TR system were calculated to be Rs. 129 and Rs. 30.8 lakhs with payback period of nearly 1.5 years with the same assumptions described in Table 3.

Efficiency enhancement of scheffler dish concentrating technology

The steam generation rate of scheffler dish concentrating technology is 3.5 to 5 kg/h. We aim to improve the steam generation rate by enhancing the heat absorbing rate of the receiver by increasing the heat transfer rate of the receiver to increase the system efficiency by 8-10%. The Computational Fluid Dynamics (CFD) codes are being used as tools for predicting efficient receiver design. Experiments at different wind velocities to study the effect of temperature distribution upon receiver surface were carried out by incorporating k-type thermocouples (sensors location as given in Fig. 2) on the receiver. The velocity ranges where convection losses are significant were studied. Fig. 3(a), (b) and (c) show variation of receiver surface temperature with time at different sensor locations on receiver, at wind velocities ≤ 0.4, 0.9, 2.5 m/s, respectively. Effect of wind velocity was studied by circulating forced air *via* fan towards the receiver throughout the experiment controlled by regulator. Wind velocity was measured with hot wire anemometer. Similar procedure was repeated with different wind velocities for corresponding days.

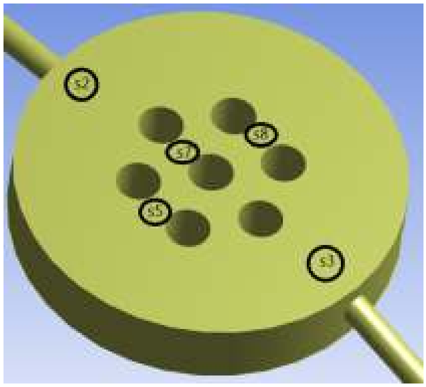


Fig. 2: Sensor positions on receiver as s2, s3, s5, s7 and s8

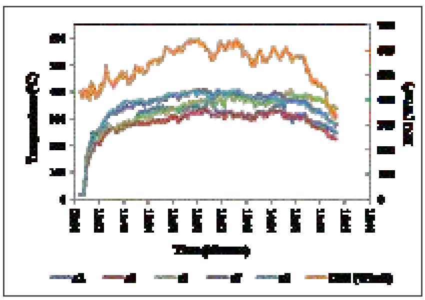
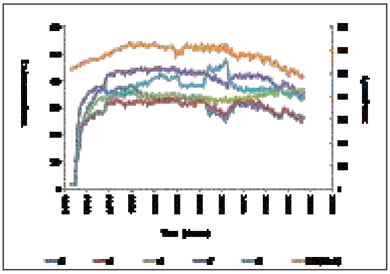
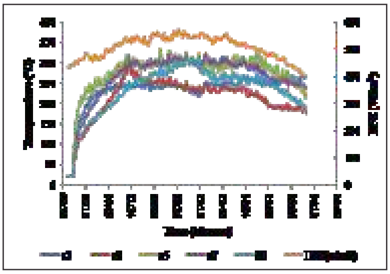


Fig. 3: Variation of surface temperature on receiver at various locations with time, (a) wind velocity is ≤0.4 m/s (ambient condition). Average DNI is 542 W/m^2



(b) wind velocity is ⩽ 0.9 m/s (ambient condition). Average DNI is 581 W/m^2



(c) wind velocity is ⩽ 2.5 m/s (ambient condition). Average DNI is 506.15 W/m^2

It is concluded that under normal atmospheric conditions where wind velocity is between 0-2.0 m/s, there is negligible effect of wind velocity on the receiver temperature. At higher wind velocities, there is a drop of surface temperature irrespective of incident radiation. Heat transfer simulation of the receiver by considering the observed convection phenomenon and temperature distribution is under progress. Recently, linear actuators have been fitted to the system as shown in Fig. 4 and experiments are in progress with semi automatic dual axis tracking system.

Fig. 4: Linear actuators fitted with the system for semi-automatic tracking

Bio-Conversion

Anaerobic digestion - Conversion of crop residues to gaseous and solid bio-fuel

Physically pre-treated rice straw (2.5 kg, < 5 mm size) was mixed with 35 L of water and incubated at room temperature for three days. Volatile fatty acid rich percolate was collected from the reactor and fed into an anaerobic hybrid reactor (AHR). The effluent discharged from the AHR was recycled to acid reactor for drawing more acid rich liquor from the rice straw. The AHR was operated at 4 different hydraulic retention times (HRTs) (15, 10, 8 and 5 day). The chemical oxygen demand (COD) of the influent was 11,000 mg/L. Leachate recovery was around 80%. COD removal rate was 68%. At 5 day HRT the bio-gas production worked out to be 59.8 L/kg TS. The solid residue left after extraction of percolate was used for pellet preparation. Good quality pellets (6 mm size) were produced. The pellets had bulk density of 609.01 kg/m^3 and calorific value of 14.842 MJ/ kg.

Effect of micro-nutrients on anaerobic digestion of crop residues in scale-up system

SPRERI technology for conversion of crop residues to methane rich bio-gas was successfully verified at 25% solid loading using outdoor batch reactors by supplementing selective micro-nutrients both at mesophilic (ambient) and thermophilic (50°C) temperatures. The average daily bio-gas production from seven successive batches of mesophilic and thermophilic digesters increased rapidly on the 2nd day and reached a peak within 5-6 days, which could be due to the degradation of soluble carbohydrates contained in the rice straw. Thereafter, bio-gas production started to decrease slowly and ceased out after 35 and 21 days, respectively. The bio-gas yields from mesophilic and thermophilic digesters was 0.279, 0.356 m^3/kg RS; 0.310, 0.396 m^3/kg TS fed and 0.336, 0.429 L/kg VS fed, respectively. The corresponding figures for the control mesophilic and thermophilic digesters were 0.198, 0.243 m^3/kg RS; 0.225, 0.270 m^3/kg TS and 0.213, 0.293 m^3/kg VS fed, respectively. The current results demonstrated that supplementation of selective micro-nutrients enhanced the bio-methanation process and most of the surplus rice straw, which is now wasted, could serve as a source of energy generation in the form of methane-rich bio-gas along with good quality manure.

SPRERI odourless bio-methanation technology for water hyacinth

Initially, the whole water hyacinth plant with roots was reduced to around 1-2 cm size using a shredder. The shredded water hyacinth was given a mechanical pre-treatment by passing through a screw press to separate the solid and liquid fractions. Around 55-60% of the total water hyacinth mass was converted in the liquid fraction and used as substrate for bio-methanation studies and the solid residues were used for briquetting. An AHR with gravel, a natural packing media, was operated at four different HRT's (14, 10, 7 and 5 day) and two different COD loadings (5 and 10 g/L). As the HRT was decreased from 14 to 7 days, the COD removal efficiencies were in the range of 69.6 to 69.1% and 68.9 to 68.5%, respectively for COD loading 5 and 10 g/L. When HRT was reduced from 7 to 5 days, COD removal efficiency was further decreased to 50.0 and 48.2%, respectively for COD loading 5 and 10 g/L. This may be due to the short contact time between the bio-film and substrate which ultimately reduced the removal rate. The rate of bio-gas production rate increased in all the reactors as the HRT decreased from 14 to 7 days. Maximum bio-gas production of 9.84 L/d was observed when the reactor was operated with COD loading of 10 g/L and 7 d HRT with methane content of 68.5%. A similar trend was observed for the reactor when operated with COD loading of 5 g/L and HRT of 7 d with bio-gas production of 5.25 L/d.

Good quality briquettes were produced from the water hyacinth solid residues in the binder-less high pressure piston type briquetting machine. The diameter of the briquettes produced was 50 mm. To evaluate water hyacinth solid residue briquettes as fuel, it was tested in a biomass combustor to generate hot air. The feeding rate of the briquettes was maintained at 8 kg/h and temperature of the hot air generated was recorded every 5 min. The heat transfer efficiency of the combustor was 55%.

Bio-methanation of dairy effluent scum

A demonstration plant to treat 500 kg/d dairy effluent scum has been installed, commissioned and performance data was collected for 12 months. After acclimatization for 2 months, the plant has been working satisfactorily for the past one year (April 2016 – March 2017) with average bio-gas production of 12 m^3/d with a methane content of 68-71%. A closed loop has been made to extract the complete energy from dairy scum by sending back the digested material to the raw dairy effluent collection tank. The bio-gas produced has been used for thermal applications in the canteen as well in-house applications and for raising the temperature of boiler feed water from 30 to 60 °C, substituting piped natural gas (PNG). After considering the annual maintenance of the plant, manpower and other costs, a simple payback period of 2.08 years has been calculated. The results demonstrated that bio-methanation of the dairy effluent scum based system is an economically viable option and it improves the overall economy of milk processing plants.

H_2S scrubber for bio-gas

H_2S content in the bio-gas produced from cattle slurry varied in the range of 10 to 50 ppm. Since, the H_2S concentration was low, to simulate the efficiency of the scrubber at higher H_2S concentrations (approx. 2500 ppm), 1% (*w/w*) gypsum was added with cattle slurry to increase the concentration of H_2S in bio-gas. Within a week the level of H_2S increased to 2400 ppm. This varying concentration of H_2S was passed through the H_2S scrubber and its removal efficiency was recorded by analyzing the outlet bio-gas of the scrubber in a portable bio-gas analyzer. The observations showed that more than 97% of H_2S was removed by using iron fillings as the packing media with varying concentrations of H_2S in the bio-gas. Further, bio-gas with different flow rates (2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 L/min) with average H_2S inlet concentration of 2500 ppm was passed through the H_2S scrubber and the outlet gas was collected and tested for its removal efficiency. For all the bio-gas flow rates tested, the H_2S removal efficiency remained greater than 99% and can be used directly for engine applications. Even though the H_2S removing efficiency was more than 97% after every regeneration method, the adsorption rate of H_2S gradually decreased with respect to regeneration. The H_2S adsorbed after first regeneration was 0.742 L/kg iron fillings and it gradually decreased to 0.735, 0.552, 0.550, 0.447, 0.340, 0.320, 0.258 and 0.252 L/kg iron fillings, respectively. The effect of regeneration of the packing media on H_2S removal efficiency is given in Fig. 5.

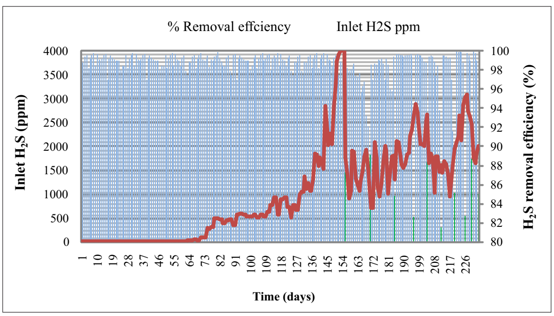


Fig. 5: Effect of regeneration of packing media on H_2S removal efficiency

Extraction of value-added by-products from bio-gas spent slurry (BSS)

BSS contains 90% moisture which creates difficulty in its handling and management. Since, it contains high organic matter, extraction of humic acid (HA) from BSS can be a novel solution to its tedious handling simultaneously producing a commercially valued product in the form of HA powder or solution. Based on laboratory findings, an HA extraction plant (50 L capacity) having two major components has been fabricated and necessary provisions were provided for refluxing and centrifuging process at constant temperature. The refluxing unit consisted of an inner chamber, outer chamber, stirrer and condenser. A heating element of 3 kW was incorporated inside the chamber. The condenser consisted of six internally connected condensing tubes. The material was fed from the upper side of the outer chamber and refluxed by the heating element and the vapours produced during the experiment condensed back to the material inside the chamber. The laboratory-scale humic acid extraction plant (LSHAEP) was operated based on the parameters selected in the laboratory. A sample of about 4 kg was mixed in 20 L of water and 1.28 kg of NaOH and 1.12 g of sodium bisulphate and was taken in to a LSHAEP refluxing unit. The solution was then refluxed at 100 °C for 1 h. The refluxed solution was then cooled at room temperature. The refluxed solution after cooling was centrifuged to separate the supernatant from the precipitate. The supernatant was taken as humate and the precipitate as humin. The humate was equilibrated to pH value less than 2 with concentrated HCl and allowed to stand overnight at room temperature to precipitate. After precipitation the solution was again centrifuged to recover HA. It was then dried overnight at 55 °C and weight of dry HA was taken. A cost analysis was made by considering the present investment and the assumption taken. The cost analysis showed that the payback period was ~ 12 months.

Green solvents for pre-treatment of biomass

More than 20 different types of natural deep eutectic solvents (NADES) reagents were prepared and evaluated for rice straw biomass pre-treatment. Among the tested NADES reagents choline chloride + lactic acid (CC-LA) based solution at a molar ratio of 9:1 was found to be optimum for effective removal of lignin from the rice straw biomass. Nearly 63% of the biomass bound lignin was solubilized and separated from the pre-treated lignocellulosic biomass. When the pre-treatment was carried out at 60 °C, the cellulose content in the pre-treated biomass residue was increased whereas the hemicellulose content was marginally decreased. Different dilutions of the NADES reagent were prepared in distilled water. The viscosity of the NADES reagent was found to decrease with increase in water addition. The pH of the NADES reagents were measured separately and it was found that it varied from 1.8 to 6.9. Based on the pH difference, the NADES reagents were categorized into two types: acidic and neutral NADES reagents. Acidic NADES reagents were CC-MA, CC-MAL, CC-LA, CC-TA, CC-CA and CC-OA, respectively. While, the neutral NADES reagents were CC-GLY, CC-ED, CC-PD and CC-UR, respectively. The effect of green solvents along with other NADES reagents on the enzyme activity of a cellulase enzyme was also evaluated. The cellulase activity was slightly decreased in CC-MAL and neutral NADES reagents when compared to the control without green solvents. While, nearly complete loss of cellulase activity was observed within 24 h in CC-MA, CC-TA, CC-LA and CC-OA, respectively, interestingly, with incubation of cellic ctec2 in high concentration (30% *v/v)* of green solvents at room temperature, the cellulase activity was increased to 35.5% in CC-GLY after 48 h whereas in CC-EG the activity was increased from 48% after 24 h. Further, enzymatic hydrolysis of pre-treated rice straw with selected NADES reagents is in progress.

Bio-ethanol production using bench scale fermentor

Based on laboratory batch and fed batch hybrid simultaneous saccharification and fermentation results (SSF) with mild alkali pre-treated lignocellulosic biomass *viz.* rice straw, wheat straw, sugarcane bagasse and corncob as a substrate, a bench scale horizontal rotary drum reactor was designed, fabricated and installed at SPRERI (Fig. 6). It has a PLC controlled LCD display and SS 316 has been used for construction. The system consists of a fully automatic table top steam generator for in-situ sterilization and is integrated with a gas analyser to measure CO_2 during fermentation. The system can be operated in static as well rotating mode. The H:D ratio is 2:1. The design pressure and working pressure are 4.0 and 3.0 kg /cm^{-2} at full vacuum and working temperature of 15-140°C. The reactor was supported by variable speed drive (6-100 rpm of the drum) and anchor type impeller for homogeneous mixing of the reactor contents. A 3 phase motor with gear is provided to rotate the drum and impeller. The reactor is also provided with a microprocessor controlled chiller/heater circulator with control temperature of 0-60°C with accuracy of 0.5°C to maintain the temperature in the water jacket. The total volume of the reactor is 50 L. Approximately 3.5-4.0 kg pre-treated biomass could be loaded to get around 700-800 mL of ethanol.

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

The main objective of the project is to produce gaseous and liquid bio-fuels from non-detoxified acid hydrolysate. Production of bio-gas and lipids from non-detoxified acid hydrolysate is a relatively new concept. Lignocellulosic biomass *i.e.* rice straw and corn cob were procured from local farms in Anand. Sugarcane bagasse was procured from a local sugar factory. The biomass were milled and screened to achieve a size of less

Fig. 6: Solid state fermentor for simultaneous saccharification and fermentation

than 5-mm mesh prior to pre-treatment. The raw materials were washed thoroughly with tap water till clean and colourless, air dried and stored at room temperature in air tight containers. Laboratory scale pre-treatment experiments were initiated with three different mineral acids (H_2SO_4, HNO_3 and HCl) at four different acid concentrations (0.5, 1.0, 2.0, 3.0 and 4.0% *(v/v)*) using rice straw and corn cob as a substrate. 150 g of pre-sized rice straw and corn cob were mixed with 450, 750, 1500, 2250 and 3000 mL of 0.5, 1, 2, 3 and 4% H_2SO_4, HNO_3 and HCl, respectively. The treatments were carried out at a fixed temperature (121 °C) for four different time points (5, 15, 30 and 45 min) and at five different solids concentrations (5, 10, 15, 20 and 33.33% *(w/v)*). The corresponding solid-to-acid ratios were 1:20, 1:15, 1:10, 1:5 and 1:3, respectively. The acid hydrolysates after dilute acid pre-treatment were recovered by filtering the contents through a double layered muslin cloth. The acid pre-treated solid residues were washed with tap water till neutral pH was achieved and sun dried prior to delignification.

As the acid concentration increased from 0.5 to 3% *(v/v)* there was an increase in xylose concentration in rice straw hydrolysate ranging from 65-142 mg/mL. Maximum xylose yields were achieved with 3% H_2SO_4 and HNO_3 at 20% solids loading for 15 min. No significant difference in the sugars concentration was observed when the substrate was treated with 2 and 3% H_2SO_4 and HNO_3 *(v/v)* for 15-45 min at 121°C. Increasing the pre-treatment period beyond 45 min, resulted in a decrease in the final sugar concentration. This may be due to the degradation of sugars at severe conditions. A similar trend was observed with corn cob when treated with the same pre-treatment conditions which were applied to treat rice straw but it led to a higher sugar concentration (120-180 mg/mL). Further, treatments with HCl yielded lower sugar concentrations with both the substrates. Experiments are being initiated with sugarcane bagasse. Furfural, HMF and phenolics were found to be 0.46±0.82, 0.52±0.68, 0.36±0.47 g/L, respectively. The furfural and HMF are degradation products of pentose and hexose sugars, respectively, while phenolics are by-products of lignin degradation.

Microalgae cultivation system under raceway pond conditions using dairy wastewater

Pilot-scale outdoor cultivation was also performed in open raceway pond (ORP) system. Raw dairy effluent (D_{eff}) was initially transferred to settler tanks for sedimentation of large particles and thereafter transferred into the ORP. Nearly 7 kL of the raw dairy wastewater (RDW) was collected and filled in the ORP. Different capacities of high rate out-door microalgal cultivation systems that can hold 60 L to 150 L were recently developed at SPRERI. These were used in scaling-up the microalgal biomass content for inoculum preperation. From these cultivation tanks, 20% *(v/v)* of the freshly grown (7 d) microalgal culture (ADW007) was taken and inoculated for ORP cultivation. Different speeds of agitation were tested (5 to 30 rpm) and it was found that a constant speed of 12 rpm using both the paddles was optimum for sufficient movement of microalgal cells through the channels within the OPR. While below 10 rpm, the flow of water was very slow, clogging the microalgal cells at the bottom of the ORP, and it had not provided sufficient agititation of the microalgae cells to permit light penetration. This led to delayed growth of microalgae.

Samples were collected and analyzed for biomass and lipid productivities. A maximum dry biomass content of 1.6 g/L was obtained on day 12 and thereafter no significant increase in the biomass was observed. Unlike, the tub system, the lipid content was decreased in ORP cultivation and reached a maximum of 28% *(v/w)* on day 12. One of the possible reasons attributed to low lipid content in out-door ORP cultivation could be the high bacterial contamination. To reduce it, the mixing process was not provided during the night period. This resulted in delayed growth of microalgae. Other possible reasons attributed to low yields could be variation in light intensity and day-light temperature during the period of cultivation. The maximum biomass content of 2.1 g/L was reached on day 21 with no difference in lipid content. The complete lipid profile of the microalgae was studied using HPLC analysis for detection of the range of fatty acids induced during growth under different growth medium conditions. A comparative evaluation of the lipid profile in synthetic media (BG11 and TAP) were also studied. Intriguingly, high levels of very long chain poly unsaturated fatty acids (PUFA) are synthesized when grown in D_{eff}. Long chain saturated fatty acid, stearic acid (C18:0) production is higher in TAP and D_{eff}, while long chain un-saturated fatty acids (palmitoleic acid (C16:1), oleic acid (C18:1), linoleic acid (C18:2), and linolenic acid (C18:3)) is induced when ADW007 was grown in BG11 medium.

The indigenously isolated microalgal strain (*Aschochloris* sps), is a potential candidate for out-door mass cultivation, utilizing 100% raw dairy effluent without external nutrients for growth in ORP. Besides, high microalgal biomass (2.1g/L) and lipid (28%) yields, the residual microalgal free-water from post-harvest processing could be effectively recycled and is suitable for irrigation. Additionally, microalgal growth in RDW and TAP medium induced high levels of PUFA production. In conclusion, besides being an environmentally safe approach, employing microalgae is a viable and effective process for zero-waste integrated bioremediation and bio-refinery technology.

Out-door cultivation using marine microalgae

Two marine microalgae designated as SPM-01 and SPM-02 were isolated from nearly 78 marine samples. Since, the growth rate of marine microalgae is comparatively lower than fresh water microalgae; an additional enrichment step was needed. To enrich the total biomass, step-wise gradual increments of microalgal culturing was performed from 10 mL to 3 L system. Each culturing step was initiated with 10% of freshly prepared inoculum. The enrichment process was initiated as soon as the culture absorbance reached 0.5 O.D at 600 nm. At this stage, the wet and dry weight of biomass was analyzed. The dry weight was found to be between 1.4 g/L to 1.6 g/L with a moisture content ranging from 78% to 83%, respectively. Simultaneously the lipid content was also analyzed and found to be 11 to 14% *(v/v)*.

Out-door cultivation was performed in an indigenously fabricated flat-plate photo bio-reactor (FPB). A maximum of 150 L of microalgae could be cultivated in the FPB. Unlike laboratory studies, in general, the out-door cultivations were performed in un-controlled conditions of light intensity and temperature. The variation in light intensities were collected on a routine basis and found to be between 12,000 Lux (morning hours) to 45,000 Lux (mid-day). Constant aeration was provided with a flow rate of 10 mt/s. Growth properties were evaluated using SPRERI isolated marine microalgae (SPM-02) in out-door conditions. The strain was enriched in 5 L glass conical flasks for 12 days in an algal growth room and transferred directly to the flat-plate photobio-reactor (FPB) containing F/2 media. 100 L of F/2 media was prepared in 100% of marine water and inoculated with 5% inoculum. Culture samples were collected daily for a period of 16 days and the growth curve was determined measuring the absorbance of the culture at 600 nm. The stationary growth phase was reached after 10 days where the dry algal biomass reached 1.54 g/L. Thereafter marginal increase in both growth rate and biomass was obtained. Snap-shots of microalgae cultivation in out-door FPB at different growth periods is shown in Fig. 7. The lipid content was evaluated from freshly harvested cells after 10 days and found to be 14.1% *(v/w)* on dry weight of biomass.

Fig. 7: Microalgae cultivation in out-door flat-plate photo bio-reactor grown in F/2 media. (top) without inoculum on day 1 and (bottom) after 10 d microalgae growth

Thermo-Chemical Conversion

Tar and SPM content reduction in producer gas using high temperature fluidized bed gasification

For better utilization of producer gas for thermal and power applications, the Tar+SPM content in producer gas should be as low as possible. For using producer gas in gas engines and turbines the tar content should be less than 100 mg/Nm^3 and 10 mg/Nm^3, respectively whereas for thermal application there is no as such limitation of tar content but still it should not exceed 3 g/Nm^3. In this direction, SPRERI-TECH fluidized bed gasification system was operated at higher bed temperature (700-900 °C) and freeboard temperature (580-795 °C) to further reduce the tar and SPM content below 1.0 g/Nm^3. Fig. 8 shows the drop in Tar+SPM content with increase in

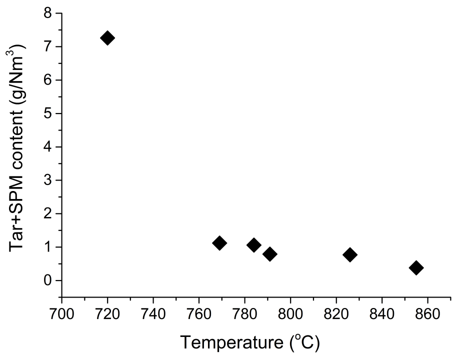


Fig. 8: Effect of bed temperature on Tar+SPM content of producer gas

bed temperature indicating high temperature operation is good for reducing Tar+SPM content in producer gas from rice husk gasification. The Tar+SPM contents of the producer gas were found to be lowest ~0.38 g/Nm^3 at bed temperature of 855 °C which is recommended for thermal applications. On the other hand, it was also observed that with increase in the bed temperature the percentage of H_2 in the producer gas was found to be consistent ~13% and therefore, calorific value of the producer gas was also found to be almost the same ~3.6 MJ/Nm^3.

The effect of higher gasification temperature on carbon conversion and thermal efficiency shows that with increase in bed temperature from 720 to 791°C, the thermal efficiency increased from 62 to 75%. However, with further increase in bed temperature to 855°C there was a drop in thermal efficiency mainly due to a drop in gas yield at very elevated temperature. On the other hand, the carbon conversion efficiency was ~90-92% over the entire range of bed temperature.

Biomass torrefaction for enhancing fuel properties of selected agro-residues

A SPRERI-TECH torrefaction reactor of capacity 1-2 kg/batch was used for carrying out torrefaction under varied process conditions such as torrefaction temperature, residence time, biomass type and size. Rice straw and cotton stalk were chosen as starting biomass materials as they are readily available at a low cost. Further, torrefaction of rice straw and cotton stalk (size: 0.6 mm) was carried out at 200, 250, 275 and 300°C reaction temperatures for average heating rate of 10°C/min. Fig. 9 shows the conversion of untreated rice straw and cotton stalk at different torrefaction temperatures. The color of the torrefied sample darkened with the temperature due to increase in fixed carbon.

With increase in the torrefaction temperature from 200 to 300°C, the mass yield showed a declining trend from 69 to 57% which is due to decomposition of rice straw at fast heating rate. A similar trend was observed in the case of cotton stalk where the mass yield decreased from 75.5 to 44%. It is also important to assess the energy yield as it signifies the energy retained by the biomass material after torrefaction. Rice straw, torrefied at 275°C, possesses excellent energy yield ~84% compared to other torrefaction temperature, confirming 275°C as the ideal temperature for rice straw torrefaction to retain the energy of the un-torrefied rice straw.

Moreover, it was observed that with increasing reaction temperature, the volatile matter, moisture content and bulk density of the torrefied biomass were found decreasing with increase in the ash and fixed carbon contents. This results in increase in calorific value of the torrefied sample for rice straw and cotton stalk.

Biomass pyrolysis of agro-residue pellets prepared using in-house pelletization facility

Pyrolysis is the thermo-chemical conversion route for production of bio-oil for thermal and power application. Pyrolysis of different selected agro-residues of size 0.6 mm (rice straw, cotton stalk and sawdust) was successfully carried out at different pyrolysis temperatures (400 to 500°C) at fixed residence time of 60 min with heating rate of 10°C/min using the in-house developed

RT 200°C 250°C 275°C 300°C

Fig. 9: Images of the torrified rice straw (top row) and cotton stalk (bottom row) at different torrefaction temperatures

SPRERI-TECH pyrolysis reactor (Fig. 10).

Fig. 10: Experimental set-up for biomass pyrolysis at SPRERI

Among three selected agro-residues, sawdust (0.6 mm size) has shown the highest bio-oil yield ~39% at 450°C followed by rice straw having a bio-oil yield ~27%. The bio-oil yield for cotton stalk decreased from 14.5% to 7.6% when the pyrolysis temperature increases from 400 to 500°C which was much lower in comparison to saw dust and rice straw. On the other hand, the bio-char yield decreased with increase in temperature from 400 to 500°C for all agro-residues. Lower pyrolysis temperatures results in greater bio-char and high temperatures favour the pyro-gas due to higher depolymerization and devolatisation reactions. Cotton stalk showed poor bio-oil yield as well as lower heating values indicating that cotton stalk is suitable for mild Pyrolysis only below 400°C.

From our preliminary experiments it was observed that the bio-oil yield for powdered biomass samples was lower for all selected biomass materials and therefore to further enhance the bio-oil yield, a few experiments were carried out on biomass pellets of different sizes. Biomass pellets were prepared using a portable pellet making machine procured from M/s Vidharabha Sales, Nagpur. Biomass pellets (both rice straw and sawdust) of size 4 mm and 6 mm were used for our present investigations. In preliminary studies, it was found that cotton stalk is not a promising feedstock for production of bio-oil due to its very high water content compared to rice straw and sawdust. So, only rice straw and sawdust were selected for detailed process analysis. The pyrolysis temperature varied from 400 to 500°C and other reaction parameters such as heating rate (10°C/min) and residence time (90 min) were kept constant. Rice straw of pellet size 4 mm pyrolyzed at 450°C showed highest bio-oil yield ~40% with heating value 19 MJ/kg and 35% water content. Whereas, sawdust of pellet size 6 mm pyrolyzed at 450°C showed lower bio-oil yield ~34% compared to rice straw but contained higher heating value 23.5 MJ/kg and lower water content of 23%. Thus, the bio-oil obtained from pyrolysis of sawdust (6 mm pellet size) was selected for bio-oil up-gradation for thermal applications.

Up-gradation of bio-oil using solvent addition approach

Biomass pyrolysis of selected agro-residues (saw dust, rice straw and cotton stalk) was carried out successfully using the in-house developed SPRERI-TECH pyrolysis reactor under optimized conditions. Bio-oil produced from saw dust pellets of 6 mm diameter showed a lower water content (23%) and higher heating value (23.5 MJ/kg) compared to 4 mm pellets size and was therefore chosen for further stabilization studies. Preliminary investigation on ageing of bio-oil with addition of 20% methanol led to improved bio-oil properties such as lower viscosity, declined acidity as well as reduced water content (~19.3%) without significant change in the calorific value compared to fresh bio-oil. Further investigation on addition of other suitable solvents and optimization of stabilizer composition is under progress. Moreover, a heavy fuel oil burner will shortly be procured for combustion studies of stabilized bio-oil. Table 6 below summarizes the properties of bio-oil as received and after up-gradation.

Table 6: Properties of bio-oil as received and after up-gradation using 20% methanol

Properties of the bio-oil	Bio-oil (fresh)	Bio-oil + 20% methanol (fresh)	Bio-oil + 20% methanol (24h@8°C)	ASTM Burner fuel D7544	Heavy fuel oil
Density, (kg/m)	1042	960	960.2	860-940 (max)	990
Viscosity, (cSt)@ 40 °C	35.4	32.1	32.5	125 (max)	5.5-24
pH	3.1	5.4	5.6	--	--
Water content, (wb, %)	23	19.2	19.3	30 (max)	0.5-1
Calorific value, (MJ/kg)	23.5	25.6	25.1	15 (min)	40.6

Development of improved natural-draft biomass cook stoves for rural households

To improve the indoor air quality of rural households and for effective utilization of biomass materials, SPRERI has been working on the design and developments of biomass cook stoves. Based on a survey carried out at rural households, two domestic cook stoves were designed and developed. An MoU has been signed with M/s Nilkanth Industry and new prototypes considering better aesthetical refinement with lower outer surface temperature of the cook stove body have been developed. Fig. 11 (a) and (b) shows our newly designed biomass cook stoves.

(a) (b)

Fig. 11: Image of the SPRERI designed (a) batch type and (b) continuous type cook stove during testing

Both the cook stoves have been fabricated and their performance was evaluated at SPRERI as per BIS norms. Table 7 summarizes the testing performance of both the cook stoves. Results indicate that the batch type cook stove has higher thermal efficiency (28.3%) and lower CO and TPM emissions compared to the continuous type of cook stove. More importantly the surface temperature at the tangible parts for both the cook stoves was less than 45°C which meets the BIS guidelines which require the surface temperature to be below 60°C. The improved performance of the cook stoves makes it more attractive for users.

Development of a forced-draft community cook stove suitable for mixed fuel wood and densified biomass fuels

A natural-draft community sized cook stove which was designed earlier, exhibited a high level of emissions. To solve this problem, primary and secondary air holes were properly designed and the new design was fabricated as shown in Fig. 12 (a). Performance of the newly fabricated natural-draft community size cook stove is given in

Table 7: Performance of the newly designed biomass cook stoves measured as per BIS norms

Cook stove type	Burning rate (kg/h)	Thermal efficiency (%)	Power rating (kW)	TPM (mg/MJ_d)	CO (g/MJ_d)	Surface temperature (°C)			
						Top	Middle	Bottom	Handle
BIS limit	—	⩾ 25	⩾ 3	⩽ 350	⩽ 5	—	—	—	—
Batch feeding	1.2	28.3	1.3	192.8	2.2	53.5	42	41	38
Continuous feeding	1.6	28.0	1.9	204.4	2.8	54.0	42	46	38

Table 8. Based on the survey carried out by the Extension Division, it was clear that 70-80% road side dhabas require 5-7 kW energy per hour for cooking. Therefore, a forced-draft cook stove of capacity ~7 kW has been designed and developed as shown in Fig. 12 (b). Primary and secondary air was given by separate fans with a regulator for controlling the flow rate of the air. Detailed thermal performance of the forced-draft community size cook stove developed was evaluated and this is given in Table 8.

Fig. 12: Images of the SPRERI designed community sized (a) natural-draft and (b) forced-draft cook stoves

Table 8: Performance of the newly designed biomass cook stoves (natural-draft and forced-draft) measured as per BIS norms

Type of the cook stove and BIS limit	Burning rate (kg/h)	Thermal efficiency (%)	Power output (kW)	Emissions			
				TPM (mg/MJ_d)	CO (g/MJ_d)	CO_2 (ppm)	CO/CO_2
BIS limit (Natural draft cook stove)	-	⩾ 25	⩾ 3	⩽ 350	⩽ 3	-	⩽ 0.04
Natural-draft (earlier-design)	-	27.0	3.5	483	9.0	5616	0.038
Natural-draft (re-designed)	3.0	29.3	4.3	320	4.2	6600	0.034
BIS limit (Forced-draft cook stove)	-	⩾ 35	⩾ 3	⩽ 150	⩽ 5	-	⩽ 0.02
Forced-draft	4.0	39.0	7.0	138	3.0	2600	0.015

Development of the biomass combustor cum hot air generator suitable for drying industries

SPRERI has successfully designed and developed a biomass combustor cum hot air generator integrated with automatic feeder for biomass feedstocks (Fig. 13). The hot air generator capacity of system is ~ 3000 m^3/h and is suitable to dry the products up to 80°C-150 °C with efficiency 65-68% for natural-draft and forced- draft operation of biomass combustor. The biomass combustor performance was evaluated for specific hot air temperature which is suitable for drying fruit and vegetables.

Fig. 13: Photograph of automatic feeder integrated biomass combustor cum hot air generator

Training and Awareness Creation

Training and Demonstrations

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

Date	Topic of lecture	Participants/training programme
Extension Education Institute, Anand Agricultural University, Anand		
22.06.2016	Lecture on Use of Renewable Energy in Agricultural domestic purpose	Group of 42 Agriculture department officials from various states
College of Renewable Energy and Environmental Engineering, SDAU, Dantiwada		
31.12.2016	Lecture-cum-interaction sessions on family size solid state and large capacity bio-gas plants, including operation and maintenance aspect and their effect in reducing pollution and global warming	Group of 200 farmers and 50 students of Renewable Energy and Environmental Engineering College

Open House

The 9th Open House was organized on February 15-16, primarily to create an awareness among the community, particularly the youth, about the importance and usefulness of renewable energy in the present scenario when the energy crises and climate change are burning issues world over.

Dr. R.C. Maheshwari, Former Vice Chancellor, SDAU, Dantiwada in his inaugural address emphasized the usefulness of different types of available renewable energy sources and technologies. He also emphasized the need for faster dissemination of renewable energy technologies, in particular, solar energy systems in the country. He called upon the youth to take the challenge of promoting RE technologies in the country. Dr. Murari Shyam, advised the youth to critically study the technologies and systems displayed in the Open House.

Approx. 2800 participants, mostly students from science, engineering and other disciplines from various schools and colleges spread accross Gujarat visited the Open House. Dozens of farmers also attended and took keen interest in the different RE technologies displayed. Scientific and technical staff of SPRERI explained various technologies to the visitors and answered their many queries (Fig. 14).

A few stalls set-up by college students to display their innovative ideas were also points of attraction. M/s Nilkanth Industries, Vithal Udyognagar and M/s Aimil Limited, Vadodara also demonstrated their renewable energy products. In order to bring awareness and to disseminate SPRERI improved biomass cook stoves, SPRERI provided a special incentive of Rs. 300/- on each cook stove costing Rs. 1300/- during the Open House.

(a)

(b)

પ્રદૂષણના વધતા ખતરાને ટાળવા વિદ્યાનગરની સ્પ્રેરી સંસ્થા દ્વારા ઇકો ચૂલાનું સફળ સંશોધન

(c)

એગ્રીકલ્ચરલ વેસ્ટમાંથી સ્પ્રેરીના વૈજ્ઞાનિકોએ ભારતમાં સૌપ્રથમ બાયો ઇથેનોલની શોધથી સર્જેલી રાસાયણિક ક્રાંતિ

(d)

Fig. 14 : Open House inauguration by Dr. R.C. Maheshwari (a). Students being explained SPRERI technologies (b). Coverage in the local newspaper (c & d)

Celebration of 'Jai Kisan Jai Vigyan' Week

SPRERI celebrated 'Jai Kisan Jai Vigyan' week during 23rd–29th December on the birth anniversaries of former Prime Ministers Shri Atal Bihari Vajpayee and late Shri Chaudhary Charan Singh. The Extension Unit organized a one day farmers meet in collaboration with KVK, Devataj in Piplav village of Anand district.

SPRERI demonstrated RE devices like, improved biomass cook stoves, bio-gas plant, solar pumping, solar rooftop system and provided information on central financial assistance (CFA) available on RE devices/technologies (Fig. 15). More than 80 farmers participated in the programs and actively interacted with SPRERI personnel.

Fig. 15: Views of the farmers participating in "Jai Kisan Jai Vigyan" programmes organized by SPRERI

Hari Om Ashram Prerit Young Scientist Award

During the 9th "Open House" inaugural session, the "Young Scientist Award" for the period 2012-2015, was conferred on Dr. S. Albert Alexander, Assistant Professor, Department of EEE, Kongu Engineering College, Perundurai, Erode Dist., Tamil Nadu by Dr. R.C. Maheshwari for his Ph.D work "Performance enhancement of solar fed cascaded multilevel inverter using new and existing techniques" (Fig. 16).

Fig. 16: Hari Om Ashram Prerit Young Scientist Award conferred on Dr. S. Albert Alexander

Krushi Mela 2017

SPRERI participated in KRUSHI MELA organized by AgroTech on 24-27 February 2017 at Anand and set-up a stall. More than 3500 farmers visited the SPRERI stall in the Mela and interacted with SPRERI staff on different RE gadgets that were demonstrated (Fig. 17). The SPRERI-TECH improved biomass cook stove and solid state bio-gas plant were the technologies of most interest to the farmers.

Fig. 17: Pictures of the farmers visiting the SPRERI stall

GEF/UNDP SGP India Meet

SPRERI participated in GEF/UNDP SGP India Meet organized by the Center for Environment Education on 15-17 March at CEE, Ahmedabad and set up a stall in the Innovative Technology Fair (Fig. 18). Representatives from various Institutes/ NGOs across the country visited the SPRERI stall. The SPRERI-TECH solar dryer, biomass based combustor and improved biomass Cook stove were the technologies of interest to most of the visitors. Further, the Workshop on Climate Change in the SGP meet was also were attended

Fig. 18: Interaction with visitors at the SPRERI stall at the GEF/UNDP SGP Innovative Technology Fair

Miscellaneous

The College of Renewable Energy and Environmental Engineering, SDAU, Dantiwada organized a one day program on "Promotion of Bio-gas Plant to Bring Prosperity in Rural Area" at Nava Nesada - Bhiladi, Dist. Banaskantha to motivate farmers to adopt this eco-friendly and sustainable technology. Dr. Gaurav Mishra and Er. Samir Vahora participated in the program and interacted with a group of 200 farmers and 50 students of RE&EE College, SDAU on various matters related to family size solid state and large capacity bio-gas plants including their operation and maintenance aspects and their effect in reducing pollution and global warming (Fig. 19).

Consultancy

Different biomass cook stove manufacturers as well as different agencies have submitted biomass cook stoves developed by them to SPRERI's TCC Division for testing as per BIS norms. All the cook stoves were tested and reports were submitted to the concerned manufacturer/agencies. Table 9 summarizes the list of the biomass cook stoves tested at SPRERI during the year 2016-17.



Fig. 19: Interaction with farmers in the program "Importance and implementation of bio-gas plant for village prosperity" at Nava Nesada - Bhiladi, Dist. Banaskantha

Table 9 : List of organizations that availed the cook stove testing facilities of TCC, SPRERI

Sr. No.	Manufacturer/Agency	Biomass cook stove type
1	NIF, Ahmedabad	Forced-draft domestic
2	Ankur Scientific Energy Techologies Pvt. Ltd., Vadodara	Natural-draft, domestic
3	M/s Adarsh Plant and Protect Ltd., Vitthal Udyognagar, Gujarat	Natural-draft community
4	Alpha Renewable Energy Pvt. Ltd., Vasna, Gujarat	Eco Natural-draft, domestic

Memorandum of Understanding

An MoU was signed by SPRERI with M/s Urja Bio Systems Private Limited, Pune for the transfer of SPRERI's technology on anaerobic filter for bio-methanation of dairy effluents.

Technology Evaluation and Transfer

Regional Test Centre

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

On August 27-28, 2016 the NABL accreditation for RTC SPRERI was reassessed and approved by the NABL core committee for the next two years and is now valid till September 11, 2018. BIS surveillance (surprise) audit was carried out on May 8, 2017.

Information on solar thermal devices received for testing and the devices for which testing was completed during the year (Table 10).

Table 10: Statement of solar thermal devices received and tested during the year

Devices	Received (Units)	Completed (Units)
Solar flat-plate collectors		
• BIS	1	2 *
• Manufacturer	4	3
Solar box cooker		
• BIS	0	0
• Manufacturer	0	2 *
ETC/FPC based solar water heating systems	8	8
Total	**13**	**15**

* Includes few devices which were received during the previous year

A proposal for enhancement of RTC facilities to carry out testing of evacuated tube collector based solar water heating systems as per new IS standards issued in year 2016 was submitted to MNRE on March 15, 2017.

Technology Evaluation and Monitoring

Field evaluation of dhaba size biomass cook stove

Demonstration-cum-awareness meetings for roadside dhaba owners were organized in nineteen villages of Anand, Kheda and Vadodara districts. Around 29 dhaba owners took part in the demonstration programmes and actively interacted with SPRERI staff. Four interested road-side dhabas/hotels have been identified and one SPRERI natural-draft improved biomass cook stove (Dhaba size) each was set up at the eateries located at Dehmi, Valasan, Samarkha(Anand district) and Kanjari (Kheda district) villages. The base data for all users have been collected for techno-economic evaluation of the improved cook stove design.

After eight months, at Ushman Nasta House, Dehmi and Rahul Patterveli, Kanjari, forced-draft cook stoves were also set up for comparison and performance monitoring (Fig. 20). The base data and data collected from users shows that the payback period was ~40 days for natural-draft cook stoves and 60 days for forced-draft cook stoves.

The acceptance level for the natural-draft improved biomass cook stoves was found to be higher than forced-draft cook stoves, due to the ease in usage and maintenance for continuous operations. In the case of forced-draft cook stoves, additional power and provision for ash removal in continuous operation of the stove was needed. However, the fuel requirement in the force-draft cook stove was less than the natural-draft cook stove. Based on the feedback, SPRERI is further designing and developing a continuous-type dhaba size forced-draft cook stove.

Technology demonstrations

Demonstration-cum-awareness programmes were organized in fifty eight villages of five districts (Surat, Banaskantha, Mehsana, Patan and Anand) for RE technologies such as SPRERI-TECH improved biomass cook stove, toilet linked bio-gas plant, solar light etc. Around 804 villagers took part in the demonstration programmes and actively interacted with SPRERI staff (Fig. 21).

Fifty units of SPRERI side-feeding **improved biomass cook stoves** for continuous operation were fabricated and one unit each was installed in 50 selected households in thirty one villages of eight districts. All the users were trained in the operation and maintenance of the stove through live demonstrations. Around 112 villagers including many women and young girls participated in the programmes and learnt

Fig. 20: SPRERI dhaba size, forced-draft biomass cook stove in use at a dhaba

Fig. 21: Views of demonstration-cum-awareness programmes of side feeding improved biomass cook stove in Patan district

about the salient features and method of operation and maintenance of the device. Base data of all the households was collected before setting-up the stoves for a socio-economic analysis (Fig. 22).

Fig. 22: The SPRERI-TECH improved biomass cook stove in use and the abandoned traditional chulha at Mahelav village

Feedback was collected from 72 households in which "SPRERI side-feeding biomass cook stoves" have been set-up in five selected villages of Anand and Kheda districts. The data collected was analyzed and the results are summarized below:

- Villagers mainly use wood, maize cobs, crop residues and dung cakes as fuel to meet their thermal needs.
- The fuel wood consumption, in general, was reduced by 20 to 30% compared to the traditional chulhas.
- Virtually no smoke was emitted while operating the cook stove.
- The cooking time was reduced by 15 to 18% compared to the traditional chulhas.
- There was no need for fuel preparation (cutting wood sticks in small pieces).
- Suffocation in the kitchen had reduced significantly
- The operation of the improved biomass cook stoves was found easy and being portable it was easy to handle.
- There was a preference for the continuous type design due to its ease in operation as beneficiaries could use the long wood sticks instead of small wood pieces in the case of side feeding.
- A few beneficiaries abandoned the use of the traditional chulha and shifted to improved biomass cook stoves.
- The time saved in the collection and preparation of the fuel and cleaning of the utensils and kitchen by women and young girls was diverted to other

income generation (*eg*. Craft, work in farm etc) or other domestic activities.

For **modified improved biomass cook stoves** (low surface temperature), demonstration-cum-awareness programmes were organized in 4 villages of Anand district. One unit each of the side feeding cook stove was set-up in five households in 2 villages and 1 top feeding cookstove was set-up at a road side corncob hawker for demonstration and collecting feedback (Fig. 23).

slurry was 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 plants of common designs. The gas at all the sites is being used for thermal applications *i.e.* the cooking and heating water. The duration of bio-gas use was found varying from 1-4 hours per day depending upon the number of family members, size of the plant and quantity of the dung fed.

Fig. 23: View of the IBCS being used at Isnav village and a corncob hawker

The **family size solid-state toilet linked bio-gas** plant of the new design (2-6 m^3/d capacity) was made and demonstrated at 17 selected farmers' sites in 14 villages of Mehsana, Banaskantha, Patan, Anand and Vadodara districts (Fig. 24). SPRERI has provided technical guidance, trained masons and selected items like inlet pipe, bio-gas burner *etc*. for the construction. Base data of all these users has been collected. The number of family members and cattle in selected beneficiaries are in the range of 4-10 and 8-25, respectively. Before setting up a bio-gas plant all the beneficiaries were using traditional cook stoves or Chulhas which emit a lot of smoke. The bio-gas at all the sites is being used for cooking meals, cooking cattle feed and heating water.

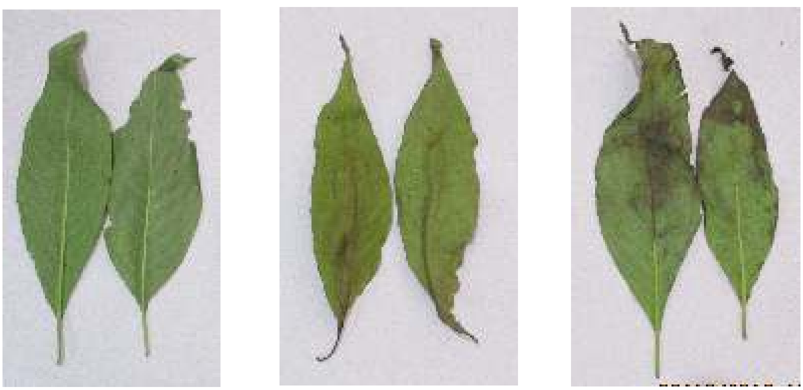
Performance monitoring of 5 family size toilet linked demonstration bio-gas plants was continued. Field performance data and slurry samples from inlet and outlet were collected. The average TSC of the feed and the outlet

SPRERI-TECH PV integrated solar forced convection dryer

SPRERI-TECH standalone type Photovoltaic module integrated solar forced convection drying system was installed at the Directorate of Medicinal and Aromatic Plants Research (DMAPR), Boriavi in PPP mode. Performance data for drying Brahmi (*Bacopa monnieri*) medicinal plant was taken up for system operation (Fig. 25). Another system was installed at Jawaharlal Nehru Government Medicinal Botanical Garden, Gandhinagar on 100% payment basis. A solar dryer was used for drying 12 kg of Justicia Adhatoda leaves. The moisture content of leaves was reduced from 69.5 to 14.4 % wb in 8 h (01 day) in a tunnel dryer. Open sun drying was also performed which took 4 days for reducing the moisture content of the leaves upto 15.1% wb (Fig. 26). A total of 9 such systems are installed at 9 selected sites in Gujarat with the help of M/s Steelhacks Industries, Anand (Table 11).

Fig. 24: Views of toilet-linked bio-gas plant and bio-gas use in kitchen

Fig. 25: PV integrated solar tunnel drier installed at Directorate of Medicinal and Aromatic Plants Research, Anand



(a) Fresh (b) Solar tunnel dried (c) Open sun dried

Fig. 26: *Justicia adhatoda* leaves

Table 11: List of locations where solar stand-alone tunnel dryers have been installed

Sr. No.	Name and Address of the Institute
1	Directorate of Medicinal & Aromatic Plants Research, Boriavi, Gujarat - 387310
2	Jawaharlal Nehru Govt. Medicinal Botanical Garden B/h. Circuit House, Sector-20, Gandhinagar, Gujarat – 382010
3	Botanical Garden, Waghai-Saputara Road, Waghai, Gujarat - 394730
4	Zandu Foundation for Health Care, Ambach Village, Pardi, Valsad, Gujarat - 396145
5	Government Ayurvedic Udyan, Nandod, Narmada, Jitnagar, Gujarat - 393145
6	Government Ayurvedic Udyan, Nani reldi, Bhuj-Kutch, Gujarat - 370001
7	Government Ayurvedic Udyan, Rupvel, Vansda, Navsari, Gujarat - 396321
8	Government Ayurvedic Udyan, Vashi, Danta, Banaskantha, Gujarat - 385505
9	Government Ayurvedic Udyan, Varod, Limdi, Dahod, Gujarat - 389180

Human Resource Development

1. Er. Asim Kumar Joshi and Er. Sampath Kumar participated in a training programme “Laboratory quality management system and internal audit as per ISO/IEC– 17025 at National Institute of Training in Standardization (NITS), Noida on Sep 13-16, 2016 and March 15-18, 2017, respectively.
2. Er. B. Velmurugan participated in a workshop “How to get CSR fund” organized by Navjivan Centre for Development” at Ahmedabad, June 5, 2016.

Participation in Meetings, Seminars and Conferences

Sr. No.	Details of the programme	Date and place	Scientist
1	Financial Assistance Programme to fund minor R&D projects	May 5,2016 GSBTM, Gandhinagar	Dr. Madhuri Narra
2	Group Monitoring cum Consultation Workshop of Core Supported groups under the SEED programme - DST, New Delhi	May 13-15-2016 BAIF - Pune	Er. Samir Vahora
3	Lecture - cum ineraction on "Important bio-energy technologies for dairy farmers"	May 20, 2016 MIT, NDDB, Mehsana	Dr. Madhuri Narra
4	Training programme on "Recent developments in non-conventional energy engineering and applications" organized at SPRERI by BBIT; Lectures delivered and site visit to M/s Vidya Dairy and Solar refrigeration system at AAU, Anand • SPRERI Solar energy technologies and their potential applicatons • Features and performance of SPRERI Bio-conversion technologies • Renewable energy technology in rural applications	May 23, 2016 SPRERI, Vallabh Vidyanagar	Dr. Mukul Dubey Er. B. Velmurugan Dr. Madhuri Narra Er. Samir Vahora Er. Asim K. Joshi Er. Sampath Kumar
5	11th National Conference on "Indian energy sector synergy with energy"	June 3-4, 2016 Ahmedabad	Dr. Madhuri Narra

Sr. No.	Details of the programme	Date and place	Scientist
6	Participated in International symposium on "Municipal solid waste management" organized by Andhra Pradesh technology development and promotion center	August 5, 2016 Vishakapatnam	Er. B. Velmurugan
7	Presentation on progress of the minor research project (MRP) entitled "Bioremediation of dairy waster by microalgae"	September 15, 2016 GUJCOST, Gandhinagar,	Dr. Adepu Kiran Kumar
8	Presented work done on bio-fuels at SPRERI including gaseous and liquid bio-fuels	September 23, 2016 SPRERI, Vallabh Vidyanagar	Dr. Sangita Kasture Dr. Datta Madamwar Dr. M. Shyam Er. B. Velmurugan Dr. Adepu Kiran Kumar Dr. Madhuri Narra
9	Project review meeting on consortium research project on Energy from Agriculture-Presentation of progress report	September 28-29, 2016 SPRERI, Vallabh Vidyanagar	Dr. Anil Dubey Dr. M. Shyam Er. B. Velmurugan Dr. Adepu Kiran Kumar Dr. Madhuri Narra Er. Pradeep Kumar
10	10th Convention of Indian Dairy Engineers Association and National Seminar on Engineering for Innovative Dairy Product and Process Development - Presentation on "Potential applications of renewable energy in dairy sector"	September 29, 2016 Anand	Er. B. Velmurugan
11	Development of next generation cost effective technologies for waste water reuse and restoring the polluted sites – as participant organized by SPU	October 3, 2016 Vallabh Vidyanagar	Er. B. Velmurugan Dr. Adepu Kiran Kumar
12	Delivered the lecture on “An overview of selected renewable energy technologies developed at SPRERI” and conduct the viva-voice examination of Ph.D student	November 24, 2016 at Shri Mata Vishno Devi University, Katra, J&K	Dr. M. Shyam
13	One-day Programme on “Promotion of bio-gas plant to bring prosperity in rural area”Lecture delivered on “Bio-gas Plants”	December 31, 2016 SDAU, Sardarkrushinagar	Dr. Gaurav Mishra Er. Samir Vahora
14	Training programme on “Advances in Energy management” organized by BVM Engineering College; Lectures delivered and site visit to M/s Vidya Dairy and Solar refrigeration system at AAU, Anand • Useful biomass technologies for meeting thermal and power requirements • Techno-economic status of solar energy technologies in the country	January 03, 2017 BVM Engineering College, Vallabh Vidyanagar	Dr. Gaurav Mishra Dr. Mukul Dubey Er. B. Velmurugan Er. Asim K. Joshi and Er. Sampath Kumar
15	Participated in Management development program on presentation skills, public speaking and interpersonal communication, IRMA	January 4-6, 2017 Anand	Er. B. Pradeep Kumar
16	Vibrant Gujarat Global Summit 2017	January 11, 2017 Gandhinagar	Dr. Mukul Dubey Dr. Adepu Kiran Kumar
17	Meeting of Doctoral Progress Committee of two Ph.D students of GTU, CSIR-CSMCRI	January 12, 2017 Bhavnagar	Dr. M. Shyam

Sr. No.	Details of the programme	Date and place	Scientist
18	Lecture –cum-interaction session on recent trends and overview of important bio-energy tehnologies for dairy farmers	January 17, 2017 NDDB, Anand	Dr. Madhuri Narra Er. Asim K. Joshi
19	Winter School on “Water and energy security in the arena of climate change” Lecture delivered • Climate change and energy security • Solar energy utilization towards pumping	January 18, 2017 Anand Agricultural University, Godhra	Dr. M. Shyam Dr. Mukul Dubey
20	Delivered lectures on Solar thermal cooling	January 19, 2017 NDDB, Anand	Er. Asim Joshi
21	Annual review workshop of consortium research project on Energy from Agriculture-Presented progress reports for 16-17 and proposed programme for 17-19 in respect of Bio-conversion and Thermo-chemical conversion	January 29, 2017 MPAUT, Udaipur	Er. B. Velmurugan Dr. Jay Pandey Dr. Adepu Kiran Kumar Dr. Madhuri Narra Er. Pradeep Kumar
22	II[nd] Annual review workshop of consortium research project (CRP) on Energy from Agriculture- Presentation of annual progress report of SPRERI Centre	January 30, 2017 Udaipur	Dr. Jay Pandey Er. B. Pradeep Kumar
23	20 “Workshop of All India Coordinated Research Project on Energy in Agriculture and Agro-based Industries, ICAR-CIAE, Bhopal. Presented progress reports for 2016-17 and proposed programme for 2017-19 in respect of Solar Energy, Bio-conversion, Thermo-chemical conversion, Liquid Bio-fuels, Demonstration of RE Systems and Energy Management in Agriculture Activities.	Jan. 30–Feb. 1-2,2017 MPAUT, Udaipur	Dr. Gaurav Mishra Dr. Mukul Dubey Er. B. Velmurugan Dr. Jay Pandey Dr. Adepu Kiran Kumar Dr. Madhuri Narra Er. Samir Vahora Er. Pradeep Kumar
24	External examiner for student's project evaluation	February 07, 2017 SDAU, Sardarkrushinagar	Dr. Gaurav Mishra
25	Expert of Renewable Energy on Committee to plan establishment of P D Patel Centre of Excellence	February 07, 2017 Charotar University of Science and Technology, Changa	Dr. M. Shyam
26	Delivered lectures on solar drying technologies and solar thermal cooling	February 11, 2017 Navrachna University, Baroda	Er. Asim K. Joshi and Er. Sampath Kumar
27	From Rice Straw Burning to Bio-gas: An Outlook for Responsible Innovation, A Brainstorming for Science and Policy	February 14, 2017 IIT New Delhi	Prof. B.S. Pathak and Dr. Madhuri Narra
28	13[th] AGRESCO (Agril. Engg) sub-Committee meeting-2017	February 17-18,2017 Junagadh Agricultural University, Junagadh	Dr. Gaurav Mishra
29	Interactive meet on “ Solar Technologies” at Mahatma Gandhi Institute for Integrated Rural Energy Planning & Development ; Lectures delivered · Solar thermal cooling · Solar drying technologies	February 18, 2017 Amrol (GEDA), Anand	Er. Asim K. Joshi and Er. Farha Tinwala
30	Annual Review Meeting of NASF Project “Development of solar-hybrid refrigeration technology for on-farm safe transient storage of horticulture produce"	February 22, 2017 New Delhi	Dr. Mukul Dubey

Sr. No.	Details of the programme	Date and place	Scientist
31	Awareness Workshop on Guidelines for Access to Biological Resources under the Biological Diversity Act, 2002.	February 24, 2017 Ahmedabad	Dr. Madhuri Narra
32	Delivered lecture on preservation of agro-produce by solar drying and cooling	February 25, 2017 Sankalp Sanstha Krishi Vigyan Kendra, Madhya Pradesh	Er. Asim K. Joshi
33	GEF-UNDP Small Grants Programme Working Meet	March 15-17, 2017 Ahmedabad	Dr. Gaurav Mishra Er. Samir Vahora Er. Asim K. Joshi and Er. Jignesh Makwana
34	Meeting with officials of M/s Mother Dairy and Urja Biosystems regarding bio-methanation plant	March 18, 2017 New Delhi	Dr. Gaurav Mishra Er. B. Velmurugan
35	Students training programme meet on " Solar Technologies" at Mahatma Gandhi Institute for Integrated Rural Energy Planning & Development; Lectures delivered • Solar thermal technologies • Solar/Biomass technologies • Solar PV technologies	March 22-24, 2017 Amrol (GEDA), Anand	Er. Asim K. Joshi, Er. Farha Tinwala and Er. Sampath Kumar

Papers Published

1. Madhuri Narra, Garima Dixit, Khushvadan C Patel, Velmurugan Balasubramanian, Jisha P James, Mahendraperumal Guruvaiah, Samir Vahora, 2016. Anaerobic digestion of Jatropha seed cake for production of renewable gaseous fuel: evaluation of digested slurry for growing crops. Agricultural Engineering Journal, ISSN: 0256-6524, 53 (2), 55-62, April-June.
2. Anil Kurchania, B. Velmurugan, Madhuri Narra, Bipin Vyas, Shakil Saiyed, 2016. Water hyacinth-a boon for bio-gas production. Akshay Urja, 10 (2), 18-20, June.
3. Kumar A. K, Parikh B. S, Shah E, Liu L. Z and Cotta M. A, 2016. Cellulosic ethanol production from natural deep eutectic solvent pre-treated rice straw. Biocatalysis and Agricultural Biotechnology, 7: 14-23, July.
4. B. Velmurugan, Madhuri Narra, Bipin Vyas, Samir Vahora, Anil Kurchania, 2016. Bio-gas from dairy effluent scum: A Potential Energy Resource. Akshay Urja, 10 (1), 34-36, August.
5. Madhuri Narra, Velmurugan Balasubramanian, Anil Kurchania, Bhim Sen Pathak, Murari Shyam, 2016. Enhanced bio-gas production from rice straw by selective micro-nutrients under solid state anaerobic digestion. Bioresource Technology, 220, 666–671, September.
6. Madhuri Narra, B. Velmurugan, M. Shyam, 2017. Conversion of crop residues to ethanol. Akshay Urja, 10 (3), 16-19, December.
7. Kumar A.K and Sharma S. 2017. Recent updates on different methods of pre treatment of lignocellulosic feedstocks -A review. Bioresourse and Bioprocessing. 4: 1-7, January
8. Madhuri Narra, Jisha P James, Jyoti Divecha,Velmurugan Balasubramanian, Disha Shah, Anil Kurchania, Manisha Harijan, 2017. Simultaneous saccharification and fermentation of low strength sodium hydroxide pre-treated rice straw for higher ethanol yields: batch and fed batch hybrid approach. Waste and Biomass Valorization, 8 (4), 1089-1103, January.
9. B. Velmurugan, Samir Vahora, Madhuri Narra, M. Shyam, Mehul Patel, Brijesh Chawla, K. S. Murthy, Lalit Patel, R. J. Desai, B. M. Patel, 2017. Bio-gas up gradation by vacuum swing adsorption – Exploring a clean energy reserve, Akshya Urja, 10 (4&5), 14-17, February-April.

Research Projects Pursued

Solar Energy

"Development of solar-hybrid refrigeration technology for on-farm (or in production catchment) safe transient storage of horticultural produce" (NASF-ICAR), Investigators: Mukul Dubey, Asim K. Joshi, Sampath Kumar, A. Gokul Raj, Samir Vahora and M Shyam (SP-2013-ST-36)

"Efficiency enhancement of scheffler dish solar concentrating technology" (SERI-DST), Investigators: Mukul Dubey, A. Gokul Raj and Arun Bollavarapu (SP-2013- ST-37)

"Design, development and performance evaluation of dual axis sun tracker" (ICAR-EAAI), Investigators: A. Gokul Raj, Mukul Dubey and Arun Bollavarapu (SP-2013-ST-38)

"Optimization of design parameters of grid independent hybrid solar/bio-gas refrigeration system for transient storage of horticultural produce" (ICAR-EAAI), Investigators: Asim K. Joshi, A. Gokul Raj and Sampath Kumar (SP-2013- ST-39)

"Study drying behaviour of stevia foliage and design solar-hybrid industrial scale system for drying of stevia foliage" (ICAR-EAAI), Investigators: Sampath Kumar, Farha Tinwala and Raja Sekhar (SP-2016- ST-40)

"Design and development of a prototype solar wax melting system for industrial application" (ICAR-EAAI), Investigators: Asim K. Joshi and Raja Sekhar (SP-2016-ST-41)

"Regional Test Centre for Solar Thermal Devices" (MNRE), Investigators: Asim K. Joshi and Jigar Andharia

Bio-Conversion

"Integrated research and development of bio-gas off-grid power solution for aquatic feed by high rate bio-methanation using effective mixing technology" (MNRE, GoI), Investigators: A. K. Kurchania, Er. Velmurugan and Madhuri Narra (SP-2014-AT-44)

"Bio-remediation of dairy wastewater by microalgae" (GUJCOST, GoG), Investigators: Adepu Kiran Kumar and Madhuri Narra (SP-2014-AT-45)

"Production of economically viable and low cost cellulases using cheaper lignocellulosic biomass or by co-culturing method" (AICRP -EAAI), Investigators: Madhuri Narra and Adepu Kiran Kumar (SP-2014-AT-46)

"Effect of supplementation of micro-nutrients on anaerobic digestion of crop residues in scale-up system" (AICRP-EAAI), Investigators: Madhuri Narra and A. K. Kurchania (SP-2014-AT-47)

"Performance evaluation MLT on development of humic acid and fulvic acid extraction pilot plant from bio-gas spent slurry to be used for use in crop production" (AICRP-EAAI), Investigators: Madhuri Narra and A. K. Kurchania (SP-2014-AT-48)

"Evaluation of bio-methanation potential of dairy effluent scum from dairy industries in Gujarat" (AICRP-EAAI), Investigators: B. Velmurugan and Madhuri Narra (SP-2014-AT-49)

"Development and evaluation of SPRERI odourless technology for bio-methanation of water hyacinth" (AICRP-EAAI), Investigators: B. Velmurugan and J. P. Makwana (SP-2014-AT-50)

"Studies on development of next generation green solvent for pre-treatment of cellulosic biomass" (AICRP-EAAI), Investigators: Adepu Kiran Kumar (SP-2014-AT-52)

"Performance evaluation of PAU H_2S scrubber for power generation from bio-gas plants" (AICRP-EAAI), Investigators: B.Velmurugan and Samir Vahora (SP-2015-AT-53)

"Development of low-cost cultivation system using dairy wastewater/fertilizer for the growth of microalgae under raceway pond conditions" (AICRP-EAAI), Investigators: Adepu Kiran Kumar, Madhuri Narra and Mahendra Perumal (SP-2015-AT-54)

"Development of a flat plate photobioreactor for cultivation of marine microalgae" (AICRP-EAAI), Investigators: Adepu Kiran Kumar Madhuri Narra and Mahendra Perumal (SP-2015-AT-55)

"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, B. Velmurugan and Adepu Kiran Kumar (SP-2014-AT-56)

"Development of a cost effective green technology for pilot-scale production of cellulosic ethanol from lignocelluosic biomass using natural deep eutectic solvents" (ICAR-CRP on EA), Investigators: Adepu Kiran Kumar and A. K. Kurchania (SP-2015-AT-57)

"Development of a continuous system for conversion of crop residues to gaseous and solid bio-fuel (briquettes/pellets) to meet the energy needs" (In-house project), Investigator: Madhuri Narra (SP-2014-AT-58)

"Development of a cost-effective green technology for lignocellulosic biomass pre-treatment using natural deep eutectic solvents" (DBT), Investigators: Adepu Kiran Kumar and Pradeep 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 B. Velmurugan (SP-2014-AT-60)

Thermo-Chemical Conversion

"Tar contents reduction of the producer gas from SPRERI fluidized bed gasifier by catalytic cracking and its thermal application in a selected industry" (ICAR-EAAI), Investigators: Jignesh Makwana and Jay Pandey (SP-2014-PG-57)

"Development of the biomass combustor with automatic feeding as well as better heat transfer use and retrofit it to one industry" (ICAR-EAAI), Investigators: Jignesh Makwana, Samir Vahora and Jay Pandey (SP-2014-PG-58)

"Development of a forced draft community cookstove using mixed fuel wood and biomass densified fuels" (ICAR-EAAI), Investigators: Jignesh Makwana, Jay Pandey and Pradeep Kumar (SP-2014-PG-59)

"Process intensification of SPRERI pyrolysis unit for adaptation with agro residue fuel pellets" (ICAR-EAAI), Investigators: B. Pradeep Kumar and Jay Pandey (SP-2014-PG-60)

"Development of torrefaction process for selected biomass and performance evaluation of the cook stoves with torrified fuels" (ICAR-EAAI), Investigators: B. Pradeep Kumar and Jay Pandey (SP-2014-PG-61)

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

Technology Transfer

"Operational Research Demonstrations and field performance analysis of dhabha size forced/natural-draft improved biomass cookstove" (ICAR-EAAI), Investigators: Samir Vahora, Dinesh Rangapara and Jignesh Makwana (SP-2014-TT-8)

"ORP on Photovoltaic module integrated solar forced convection drying system" (ICAR-EAAI), Investigators: Asim Kumar Joshi and Samir Vahora (SP-2014-TT-10)

"Setting-up and performance monitoring of SPRERI domestic improved biomass cookstoves in selected five Gujarat villages" (ICAR-EAAI), Investigators: Dinesh Rangapara, Samir Vahora and Pradeep Kumar (SP-2016-TT-12)

"Energy auditing of the rural households in Gujarat and scope for RE for cooking and illumination" (ICAR-EAAI), Investigators: Samir Vahora and Dinesh Rangapara (SP-2014-EM-2)

"Energy audit and energy efficiency enhancement of banana farming in Gujarat" (ICAR-EAAI), Investigators: Dinesh Rangapara and Samir Vahora (SP-2016-EM-3)

"Rural Development Programmes" (GoG) Investigators: Samir Vahora and Dinesh Rangapara (SP-2016-RD-1)

"DST Core Support Project" (DST, GoI) Investigators: Samir Vahora (SP-2017TT-13)

Visitors

1. Dr. Sangita Kasture, Joint Director, DBT, New Delhi visited SPRERI on September 23, 2016.
2. Team from Urja Biosystems, Pune visited SPRERI on February 7, 2017.

SPRERI Team

Director

Dr. M. Shyam (upto 06.03.2017)

Dr. Gaurav Mishra (*w.e.f.* 07.03.2017)

Scientists

Solar Energy Division

Dr. Mukul Dubey, I/C Head

Er. Asim Kumar Joshi

Er. Gokul Raj (upto 24.06.2016)

Er. Sampath Kumar Gundu

Er. Farha Tinwala

Er. Arun Bollavarappu

Er. Rajashekhar (upto 24.06.2016)

Er. Shakil Saiyed (upto 16.12.2016)

Mr. Shaival Dalwadi

Bio-Conversion Technology Division

Dr. A. K. Kurchania, Head (upto 29.08.2016)

Er. B. Velmurugan, I/C Head (*w.e.f.* 30.08.2016)

Dr. Adepu Kiran Kumar

Dr. Madhuri Narra

Er. Disha Shah (upto 07.02.2017)

Er. Bipin Vyas

Dr. Shaishav Sharma (*w.e.f.* 28.03.2016)

Er. Gaurav Dixit (*w.e.f.* 01.09.2016)

Ms. Kumud Macwan (*w.e.f.* 01.12.2016)

Ms. Ekta V. Shah

Ms. Manisha Harijan

Mrs. Aesha D. Patel

Thermo-Chemical Conversion Division

Dr. Jay Pandey, I/C Head

Er. Pradeep Kumar

Er. Jignesh Makwana

Mr. Harshad Suthar

Extension

Er. Samir Vahora, I/C Head

Shri A.K.Chauhan (upto 30.09.2016)

Er. Dinesh Rangapara

Er. Kalu Kachchhava

Administration

Mr. P. Amar Babu

Mr. Kailas Trivedi

Ms. Pragna Dave

Mr. Hitesh Dalwadi

Mrs. Aida Mascarenhas

Mr. Hasmukh Vaghela

Technicians and Drivers

Mr. Jayesh Parmar

Mr. Bhupendra Prajapati

Mr. D.M. Harijan

Mr. Minesh Suthar

Mr. Ramesh Bhoi

Mr. Rajesh Machhi

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

Ms. Manjula Vadhel

Mr. Shailesh Solanki

Mr. Mukesh Jadav

Mr. Ashok Mochi

Balance sheet as on 31.03.2017

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE - VALLABH VIDYANAGAR
BALANCE SHEET AS ON - 31 - 03 - 2017

FUNDS & LIABILITIES	2016	2017
CAPITAL FUND		
As per last year	10,82,669.20	10,82,669.20
PROJECT FUND		
Balance from last year (-)	11,62,607.82	(-)14,44,241.37
Add / Less during the year (-)	2,81,633.55	(+)76,87,889.06
(Annexure - A) *(-)	14,44,241.37	62,43,647.69
EAR MARKED FUND		
1. Building Fund Provision	33,64,376.00	33,64,376.00
Add : During the year	-	-
	33,64,376.00	33,64,376.00
2. Depreciation Investment Fund	4,55,244.00	4,55,244.00
3. R & D Fund (As per last year)	64,51,074.73	68,17,459.73
Add : During the year	3,66,385.00	1,16,679.00
Less : During the year (Anne - D)	68,17,459.73	69,34,138.73
DONATION		
Balance from last year	10,56,001.00	11,29,001.00
Add : During the year	73,000.00	55,000.00
	11,29,001.00	11,84,001.00
PROJECT EQUIPMENT		
Depreciated value of Equip.from last year	7,50,82,630.35	8,18,84,821.35
Add : During the year	68,02,191.00	75,52,897.00
Less : Depreciation Annex. C1	(-)8,18,84,821.35	8,94,37,718.35
DEPRECIATION FUND		
As per Block - As per Annexure-B	61,22,233.30	62,52,964.30
LIABILITIES		
1. Contigent Development Fund	1,33,400.00	1,33,400.00
2. Graduity Fund	47,16,299.94	59,11,719.63
3. Endowment Fund -	13,14,351.75	13,43,499.75
Add : During the year	29,148.00	56,480.00
Annexure - E	13,43,499.75	13,99,979.75
4. Staff Welfare Fund	92,551.50	1,39,659.50
5. Share & Care Fund	1,52,835.00	1,52,835.00
6. Quiz Programme Fund	58,262.00	58,262.00
7. Maintenance Fund (Core Grant)	5,12,879.00	5,12,879.00
Income & Expenditure A/C SURPLUS / LOSS		
From Last/current Yr Balance Sheet	2,02,347.38	2,06,465.58
Add / Less During the year	4,118.20	
TOTAL	2,06,465.58	
Add - during the year - 2016-17		46,265.89
TOTAL		2,52,731.47
TOTAL	**2,47,42,934.63**	**3,40,84,797.27**

ASSETS	2016	2017
FIXED ASSETS		
1. Furniture & Fixtures	2,49,808.62	2,49,808.62
2. Electric Fittings	1,44,167.85	1,51,987.85
Add : During the year	7,820.00	10,363.00
	1,51,987.85	1,62,350.85
3. Mobile Phone	19,600.00	19,600.00
4. Institute Equip.(R & D / Others)	10,71,372.00	10,71,372.00
5. Jeep GJ-23A-5102	7,47,273.00	7,47,273.00
6. Car GJ-23 AF 0282	5,85,597.00	5,85,597.00
	28,25,638.47	28,36,001.47
INVESTMENT		
1. Fixed Deposit	49,71,265.00	1,24,71,265.00
2. Deposit in LIC - Gradulty Scheme	47,16,299.94	59,11,719.63
	96,87,564.94	1,83,82,984.63
LOANS & ADVANCES		
1. Tax Deduction at Source	5,92,683.00	4,67,099.50
2. Telephone Deposit	20,313.00	20,313.00
3. CGM Deposit (Oil Diesel & Petrol)	12,400.00	12,400.00
4. Indian Oxyzen Ltd., Deposit	4,252.94	4,252.94
5. Mobile Phone Deposit	4,680.00	4,680.00
6. Broad Band Security Deposit	3,000.00	3,000.00
7. Gas Cylinder Deposit	10,350.00	10,350.00
8. Security Deposit (GEB - New OP)	1,00,920.00	100,920.00
9. Loan to Staff & Advance to Project	7,81,155.00	777,870.00
10. Intrest Accrued	5,705.50	189,193.08
	15,35,459.44	1,59,00,78.52
BALANCE :		
Bank Balance	1,06,77,394.78	1,12,40,298.65
Cash Balance	16,877.00	35,434.00
	1,05,94,271.78	1,12,75,732.65
TOTAL	**2,47,42,934.63**	**3,40,84,797.27**

Accounts Officer
Sardar Patel Renewable Energy Research Institute

Director
Sardar Patel Renewable Energy Research Institute

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

B. C. PATEL & CO. ANAND Mem.No. 32231 CHARTERED ACCOUNTANTS

24 JUL 2017

Abbreviations

AHR	-	Anaerobic hybrid reactor
AICRP	-	All India Coordinated Research Project
Amb	-	Ambient
Avg.	-	Average
BE	-	Betaine
BG	-	Blue green
BGP	-	Bio-gas plant
BIS	-	Bureau of Indian Standards
BSS	-	Bio-gas spent slurry
CA	-	Citric acid
CapEx	-	Capital Expenditure
CC	-	Choline chloride
CFA	-	Central Financial Assistant
CFD	-	Computational Fluid Dynamics
CIAE	-	Central Institute of Agricultural Engineering
cm	-	Centimeter
COD	-	Chemical oxygen demand
cu m	-	Cubic metre
d	-	Days
D	-	Diameter
D_{eff}	-	Dairy effluent
DNI	-	Direct normal insolation
DST	-	Department of Science and Technology
EAAI	-	Energy in Agriculture and Agro- based Industries
EG	-	Ethylene glycol
ETC	-	Evacuated tube collector
FPB	-	Flat-plate photobio-reactor
FD	-	Forced-draft
FPC	-	Flat-plate collector
FPU	-	Filter paper units
GEDA	-	Gujarat Energy Development Agency
GLY	-	Glycerol
GoG	-	Government of Gujarat
GoI	-	Government of India
h	-	Hour
H	-	Height
HA	-	Humic acid
HCl	-	Hydrochloric acid
HMF	-	Hydroxymethyl furfural
HNO_3	-	Nitric acid
HRT	-	Hydraulic retention time
H_2SO_4	-	Sulphuric acid
IBCS	-	Improved biomass cook stove
ICAR	-	Indian Council of Agricultural Research
ISO/IEC	-	International Organization for Standardization (ISO) and International Electro technical Commission
kg	-	Kilogram
KVK	-	Krishi Vigyan Kendra
kW	-	Kilowatt
L	-	Litres
La	-	Lactic acid
LCD	-	Liquid crystal display
LSHAEP	-	Laboratory scale humic acid extraction plant
MA	-	Malic acid
MAL	-	Malonic acid
mg	-	Milligram
min	-	Minutes
MJ	-	Mega joule
mm	-	Millimeter
MNRE	-	Ministry of New and Renewable Energy
MW	-	Megawatt
m^3	-	cubic meter
NABL	-	Accreditation Board for Testing & Calibration Laboratories
NaOH	-	Sodium hydroxide
NADES	-	Natural deep eutectic solvents
NASF	-	National Agricultural Science Fund
ND	-	Natural-draft
NITS	-	National Institute of Training in Standardization
OA	-	Oxalic acid
OD	-	Optical density
O&M	-	Operation and Maintenance
OpEx	-	Operational Expenditure
ORP	-	Operational research project/Open raceway pond
PAU	-	Punjab Agricultural University
PD	-	Propane 1,2-diol
PLC	-	Programmable logic controller
ppm	-	Parts per million
P-P-P	-	Public private partnership
PNG	-	Piped Natural Gas
PUFA	-	Polyunsaturated fatty acid
PV	-	Photovoltaic
Qty	-	Quantity
R&D	-	Research and development
RDW	-	Raw dairy wastewater
RE	-	Renewable energy
RE&EE	-	Renewable Energy and Environmental Engineering
RH	-	Relative humidity
RS	-	Rice straw
RTC	-	Regional Test Centre
SDAU	-	Sardar Krushinagar Dantiwada Agricultural University
SERI	-	Solar Energy Research Initiative
SPM	-	Suspended particulate matter
SPRERI	-	Sardar Patel Renewable Energy Research Institute
SS	-	Stainless steel
SSF	-	Simultaneous saccharification and fermentation
TA	-	Tartaric acid
TAP	-	Tris-acetate-phosphate
Temp	-	Temperature
TPM	-	Total particulate matter
TR	-	Ton of refrigeration
TS	-	Total solids
TSC	-	Total solid concentration
UR	-	Urea
VAM	-	Vapor Absorption Machine
v/v	-	Volume per volume basis
VS	-	Volatile solids

Contact for further information:

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