SPRERI
Striving for Excellence

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE

Annual Report | 2019-20

Sardar Patel Renewable Energy Research Institute

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Highlights of the Year

India, under the Solid Waste Management (SWM) action plan was following Municipal Solid Waste (MSW) rules 2000 for long. In order to have more clarity on the roles and responsibilities of all the stakeholders and to give proper definition to the waste generators, introduced revised SWM rules in 2016. The Ministry of Environment, Forest and Climate Change on March 2020, issued amendments to the SWM Rules 2016 and notified that this rule is applicable to all villages with a population more than 3000.

Under Swachh Bharat Mission and SWM Rules 2016, it becomes important to have clean scientific solutions for MSW treatment, being generated in such villages and B or C-class cities. To address MSW treatment, SPRERI has developed a patented clean & odorless bio-methanation process to treat the wet organic fraction of MSW and other fruit and mandi waste and is developing a 3.5 TPD bio-methanation plant at Anand, Gujarat. The project is sponsored by the Department of Biotechnology, Government of India and aims to convert the wet organic fraction of MSW from all commercial units i.e., hotels, eateries, restaurants, and street vendors, etc. The proposed project will address the segregation of waste at source, collection, and transportation till the plant site and aims to provide the bio-gas from the plant to replace the PNG use at kitchens of a charitable hospital, Shree Krishna Hospital. The bio-fertilizer produced during the process is envisaged to be sold to farmers at a subsidized rate. Separate agreements are also made with Vallabh Vidyanagar and Karamsad nagar palikas to support the project. In addition to this, awareness creation and efforts to inculcate waste management practices will be also introduced.

SPRERI in-line with the Government of India's broad agenda continues its research and development in renewable energy technologies. The bio-chemical conversion division, is addressing the stubble burning issue of Punjab and Haryana. Its team is developing a technology and has filed a patent for converting crop-residues to gaseous bio-fuel in a continuous mode.

The thermo-chemical conversion division, team has up-scaled the developed loose biomass-based fluidized bed gasification system to 100 kg h^{-1} capacity after rigorous testing. The team has also developed 4.75 kW_{th} capacity dhabha-size forced-draft biomass cookstove to cater to the thermal needs of small dhabhas, snack-centers, etc. The demonstration and initial field implementations are in the process along with the technology transfer (extension) division team.

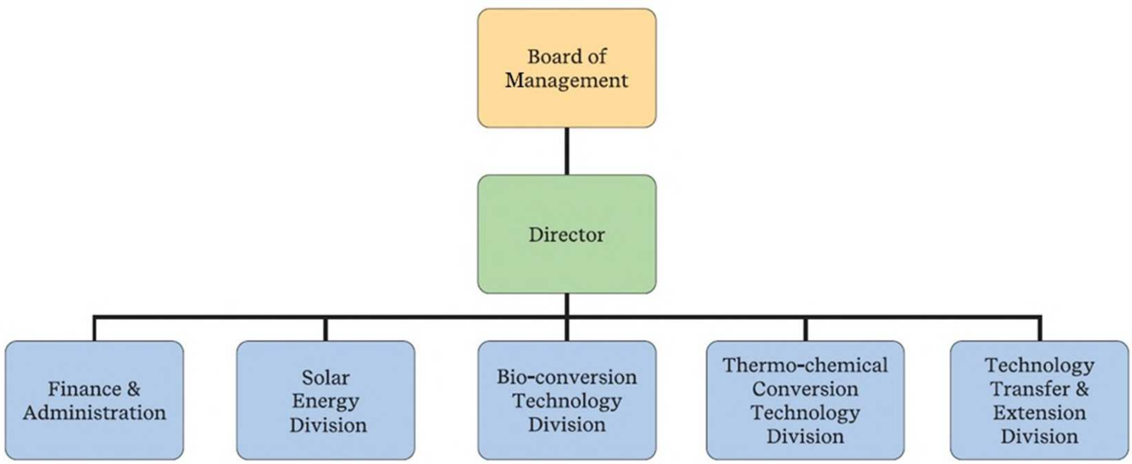
The solar energy division's, research projects have focused on various concepts including nano-fluid based solar thermal collectors, thermal storage based cold storages, solar air heaters integrated with PV for combined thermal and electrical applications etc. This work is still in progress.

SPRERI has been engaged in various training programs during the year. The technology transfer (extension) division, during the year, has installed more than 500 SPRERI developed improved biomass cookstoves in different parts of Gujarat State. In addition to this, SPRERI accomplished a project on improving the working environment of tribal families during cooking through introducing SPRERITECH domestic size improved biomass cookstove supported by Jharkhand Tribal Development Society (JTDS), Ranchi. In the project, 1000 number of cookstoves were implemented in 4 districts namely Pakur, Dumka, Sahibganj, and Godda. The project has brought numerous benefits in the lives of tribal people and has helped them generating revenue around Rs. 4745/hh/y with saving in wood consumption of ~2.37 tonnes/y/cookstove.

The annual event "Open House" was organized at SPRERI on February 14-15, 2020. More than 2700 persons, primarily under-graduate and post-graduate students and faculty of engineering, management, and science colleges from all over Gujarat, participated.

The Organization & Structure

Sardar Patel Renewable Energy Research Institute (SPRERI), established in 1979, is an autonomous and not-for-profit organization managed by a Board comprising leading technologists, scientists, industrialists, and representatives of Central and State Governments. It is recognized by the Department of Scientific and Industrial Research, GoI, as a Scientific and Industrial Research Organization. It is also approved as a Research Association for the purpose of clause (ii) of sub-section (1) of section 35 of IT Act, 1961. It generates most of its operating funds through projects assigned 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. As a renowned RE research institution it 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 RE devices and systems developed at SPRERI are now manufactured by selected industries and supplied to end users. In addition, the promotion of RE technologies is pursued through field evaluation and demonstrations, training and entrepreneurship development, awareness programmes and integrated development of selected tribal villages. SPRERI organizes "Open House" for two days every year to create awareness about RE technologies, among citizens, particularly the youth. Under graduate and post-graduate students from all over the state visit SPRERI during Open House.



Vision & Mission

VISION

- SPRERI will be an organization that will develop environment-friendly RE technologies that are efficient and economically viable for society

MISSION

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

Board of Management

Dr. Amrita Patel	Trustee, Charutar Arogya Mandal, Karamsad
Prof. B.S. Pathak	Ex-Director, SPRERI and Energy Consultant KC-5, Kavi Nagar, Ghaziabad
Shri P.C. Amin	Director, Elecon Group of Companies M/s Elecon Engineering Co. Ltd., Vallabh Vidyanagar
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Dr. Gaurav Mishra	Director, SPRERI, Vallabh Vidyanagar (Member-Secretary)

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

In previous experiments, air was introduced behind the absorber sheet of the PVT/Air collector, which led to high temperature of the PV module and resulted in less power generation. Therefore, the system was modified and now air was made to flow in between PV module and absorber plate collector i.e., exact below of the PV module. Experiments were thus performed to compare the electrical and thermal performance of thermal collector and PVT collector for the new configuration of airflow. The test set-up was arranged in the same manner as in the earlier study (Fig. 1).

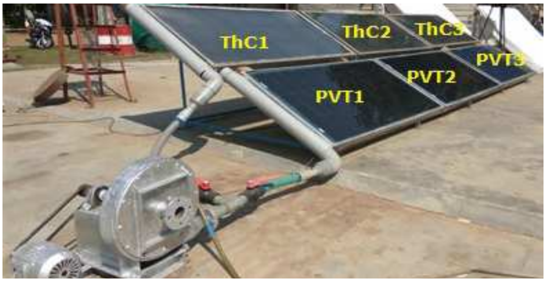

Fig.1 Solar Thermal (ThC) and PV+thermal (PVT) collector test set-up

PVT1 to PVT3 represent PV integrated thermal collector and ThC1 to ThC3 denote thermal collectors. The frequency of occurrence of air temperature measured at different sensor points in thermal and PVT collectors was estimated and is presented in Fig. 2.

The inlet air temperature remains in the range 15°C to 30°C. The maximum temperature observed at the outlet of ThC1, ThC2 and ThC3 was 49°C, 61°C and 73°C, respectively. Similarly, maximum outlet temperature at the outlet of PVT1, PVT2 and PVT3 collector was 41°C, 47°C and 53°C, respectively. As expected, temperatures at the outlet of the thermal collectors were significantly higher than PVT collectors. Although the outlet air temperatures from PVT collectors were lower than the thermal collectors, they were found to be suitable for drying application.

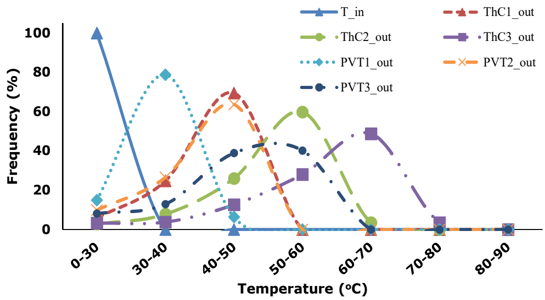

Fig.2 Frequency of occurrence of air temperature through thermal collector array at 400 $m^3 h^{-1}$ during winter season

Efficiency of PV module in open and in PVT mode were also determined (Fig. 3) to show the effect of temperature on its performance. Temperature is found to have an inverse relation with the performance of PVT collector. It was observed to get reduced with increase in the temperature. Average efficiency of the open PV module was 1.7% higher than PVT collector module. From the results it can be stated that the hybrid PVT collector can serve the dual purpose for heat and electricity.

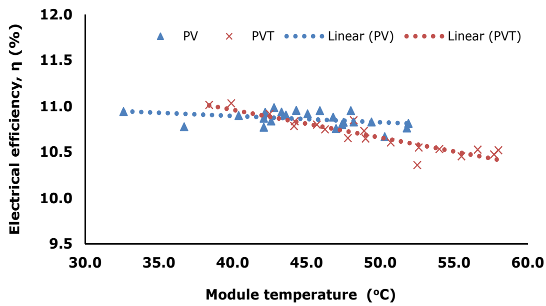

Fig.3 Efficiency of PV and PVT module at different temperature

1.2 Efficiency enhancement of solar thermal collectors by using nano-fluids

Two similar size solar thermal flat plate collectors for water heating were designed. The performance of one of the systems was tested using prepared nano-fluid in direct absorption and indirect absorption modes as shown in Fig 4(a) and (b). The other collector was also tested simultaneously as conventional solar water heating collector. The performance of the nano-fluid based collector was compared with the conventional solar water heating collector.

Fig.4 (a) Working of nano-fluid in indirect absorption mode (b) Working of nano-fluid in direct absorption mode

In direct absorption mode, the nano-particle (0.02% Al_2O_3 concentration) settled down within two days and accumulated on the absorber sheet in the collector. However, tests were continued and performed at different flow rates, the results obtained are shown in Table 1.

Table 1 Comparative performance data of two collectors at different flow rates

S. No.	Water flow rate ($L\,h^{-1}$)	Outlet water temperature range (°C)		Average thermal efficiency (%)		Average solar radiation ($W\,m^{-2}$)
		With nano-fluid	Without nano-fluid	With nano-fluid	Without nano-fluid	
1	30	44-67	40-55	48.15	32.56	758.34
2	40	45-56	36-50	62.90	40.81	789.09
3	60	45-59	36-55	50.27	46.03	694.85

In indirect absorption mode, the nano-fluid was prepared from Al_2O_3 (0.1%) with 2 h sonication and same was used in one of the solar collectors as heat transfer fluid in a closed loop. The collected heat from the collector is transferred to a water storage tank using coil type heat exchanger as shown in Fig 5. Further, the efficiency of the nano-fluid based collector and water-based collector were estimated and found ranging between 28% and 78%, and 10% to 57%, respectively. The average efficiency of the collector with nanofluid was found to be 57% compared to the 30% efficiency of the water-based collector. Further, the studies are continuing with soot particle generated from waste engine and available from other possible sources.

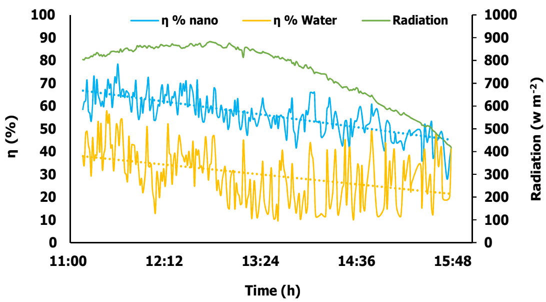

Fig.5 Variation of efficiencies of collectors with nano-fluid, without nano-fluid and solar radiation with time

1.3 Design, development and performance evaluation of a down-scaled PV integrated low tunnel dryer

Developed ETC prototype was equipped with 40 W solar PV panel to power two 24 VDC and 0.7 A BLDC fans, which makes the system grid free. The system was tested for no load condition. The average air flow rate and temperature rise observed for the entire day along with the thermal efficiency obtained are shown in Fig. 6. The average air temperature at outlet of ETC collector was observed above 60°C between 11.00 am and 5.00 pm. The estimated efficiency of the system during morning hours i.e., between 8.00

am and 10.00 am varied between 30% and 50%. Thereafter, until 2.00 pm, the efficiency remained within 50-60%. The efficiency was observed to increase with decrease in radiation whereas change in flow rate was negligible. This increase in efficiency is due to residual heat in the ETC tubes and steel conduits. Further system testing for drying various items is in progress.

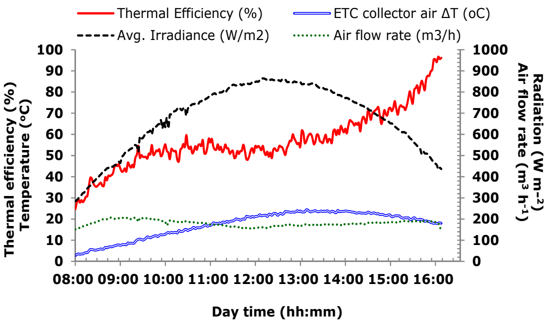

Fig.6 ETC dryer collector average performance

1.4 Solar evacuated tube with heat pipe collector for cooking application

In most of the solar cooking technology, tracking is required to keep the focus on the receiver, which makes the system costly, and limits the use of these devises for outdoor cooking. However, for solar evacuated vacuum tube with heat pipe, its round absorber surface passively tracks the sun throughout the day, so no mechanical tracking device is required. It also has stagnation temperature of 220°C with efficiency in the range 60-70%. In view of these features, a study was taken up to evaluate its potential for cooking applications.

A test prototype having twenty ETC with heat pipe in series, a flat box as cooking surface, a jacketed SS vessel and a pump for circulation of heat transfer fluid was developed, as shown in Fig. 7. Under stagnation temperature test (no load test), maximum surface temperature of the SS vessel was observed around 165°C while the collector outlet maximum temperature was around 173°C. Overall, the surface temperature remained above 100°C till 6.00 pm i.e., for around 6.5 h. For water boiling test, total 8 to 9 batches of water (3 L each) were heated up to 95°C in a whole day. The system was also tested for rice & tuvar dal cooking. Further testing is in progress.

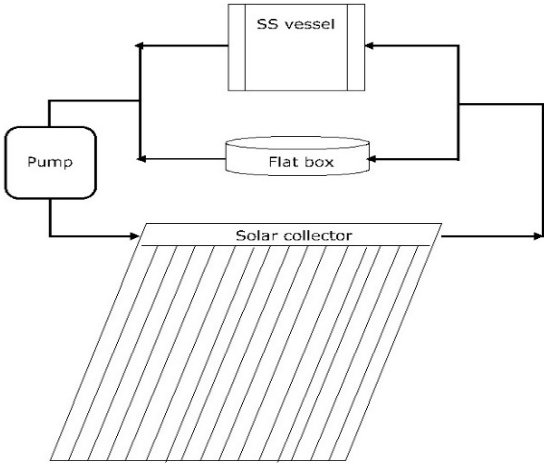

Fig.7 Schematic ETC with heat pipe-based cooking system

1.5 Thermal storage integrated SK-14 solar concentrating cooker

Systems that can allow indoor cooking and are free from indoor pollution are highly desirable. Existing solar cooking systems need to be operated in the open sun, which is inconvenient. In the proposed project, the aim is to develop a thermal storage based cooking device that may allow the user to cook comfortably indoor. The stored energy will be utilized during non-sunny hours also. In addition, it is expected to match all the cooking requirements of Indian cuisine.

An in-silico model of solar concentrator with heat storage receiver was prepared in SolTrace (Fig. 8) and optimum design parameters for the system, i.e., aperture diameter, focus length and distance between focus and receiver were yielded. Further, a thermal storage device suitable to store heat at a temperature between 250°C and 300°C was designed.

Mixture of two different-phase change material or 2.4 kg was filled in the thermal storage vessel. Thermal charging and discharging cycles were performed in indoor room environment using electric heater as a heat source. In Fig 10, sensors CH101, CH102, CH103, CH104, CH111 and CH112 represent the temperature of heater, outside vertical surface (two sensors), top of vessel, PCM temperature at 2 cm and 6 cm above bottom heating surface, respectively.

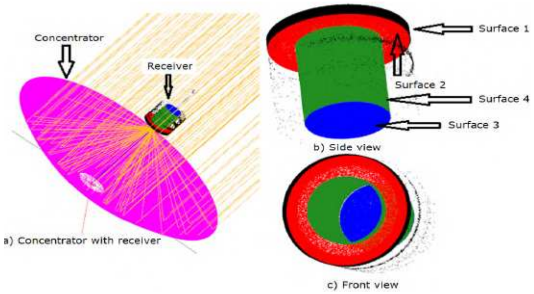

Fig.8 a) SolTrace model of the concentrator with receiver b) side view and c) front view

As shown in Fig. 9, the melting zone indicates that PCM melted at 236°C. The curve clearly indicates the charging period to be shorter than discharging period. The charging is completed in approx. 120 min at charging temperature about 800°C. It was further observed that the device took about 195 min to drop its temperature to 100°C. Further, testing of charging the thermal storage device will be performed in outdoor conditions using the in-house developed concentrator.

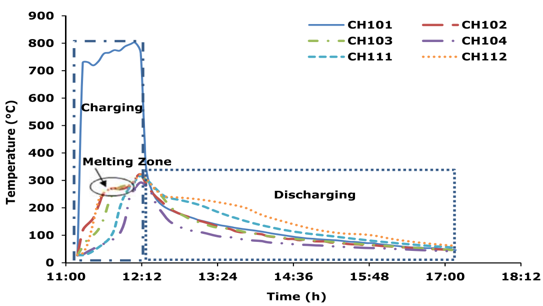

Fig.9 Charging and discharging behavior of thermal storage device with mixture of PCM material

1.6 Design, development and performance evaluation of a thermal energy storage based indirect solar dryer

Low efficiency and operation only during the sunny hours are the limitations of solar direct/indirect air heating dryers. A thermal energy storage based indirect solar dryer uses water in the energy collection loop and has a thermal storage tank. The idea of using water as working fluid in the collection loop is to enhance the collection performance by taking advantage of the higher thermal conductivity of water. Moreover, integration of the thermal storage tank will allow the system to run during non-sunny hours and helps in stabilizing the dryer temperature by eliminating temperature fluctuation due to variation in solar radiation intensity during the day.

Fig.10 Front image and side image of installed solar ETC heat pipe and thermal energy storage based indirect dryer

A testing prototype has been developed as shown in Fig. 10. The system comprises four ETC heat pipe collectors, thermal energy storage tank, heat exchanger and dryer chamber. The thermal energy storage tank was filled with 400 L water for sensible heat storage. Preliminary testing was performed in two modes. In the first mode, water was heated with solar collectors during the daytime (9.00 am - 5.00 pm) and used for heating air during 5.00 pm - 12.00 am. The air temperature was observed above 50°C for three hours at air flow rate 270±50 $m^3 h^{-1}$.

In the second mode, both operations i.e., heating of water in the storage tank and heating air through hot water were performed simultaneously during sunny hours. The energy demand and supply were found synchronized during the test. The air temperature remained above 60°C till 3.30 pm and dropped to 52°C by 5:00 pm as a result of drastic change in radiation value after 3.15 pm. Further testing is in progress.

1.7 Feasibility study on solar compound parabolic concentrator for desalination of ground water

To avoid consumption of high TDS water, RO systems are used in urban areas. But for rural/tribal people simple technologies are needed to avail safe drinking water. Also, in the RO system ¾ part of water is wasted to generate ¼ part of drinkable low TDS water. As an alternative to this practice, one can have solar still. One major issue with a solar still is low distillate generation/day. To enhance the distillate generation/day a solar collector was integrated with a simple solar.

A prototype of a solar still integrated with ten heat pipe tubes (ETC HP still) was developed and shown in Fig. 11, wherein evacuated tube-based heat pipe were adapted to accelerate the water evaporation in the basin. The performance of the developed solar still was compared with a SPRERITECH simple design solar still (Fig. 11) having FRP make round basin and conical cover of transparent LDPE sheet.

The overall area covered by ETC HP is still 37.9% more than an FRP still. The performance of the new prototype was carried out. Initial water load was kept 30 L in both the systems. The distillate production observed was approx. 164% higher in day time and around 71% higher in night time than the distillate in the FRP still. Cost per litre of water production through the ETC HP still and the FRP still were estimated around Rs. 3.7 & Rs. 4.4, respectively. Further system up-gradation work is in progress to enhance its performance.

Fig.12 Experimental set-up of SPRERITECH FRP solar still

1.8 On-farm demonstration and performance analysis of an off-grid RE driven cold storage

The Bilateral Indo-Danish project aims to develop and demonstrate a pilot-scale standalone RE driven low temperature transient storage facility for perishable agro-produce suitable for on-farm non-electrified catchments areas. It will reduce post-harvest losses and ensure more revenue to farmers.

Dialogue with a few farmers is in process to select a suitable site for the demonstration. Two sites have been visited. Discussions with both the farmers are in progress to finalize for proposed system installation. Meanwhile, a survey to identify a few more potential users is also in progress.

The required background knowledge was shared with the Denmark Team to enable them to initiate their work on simulation and modeling studies. The Danish team consisting of Dr. Ahmad Arabkooshar and Dr. Meisam Sadi visited SPRERI during November 6-10, 2019 and visited the identified farm sites and the solar-biogas hybrid refrigeration system installed by SPRERI at College of Food Process Technology on Bio-energy at Anand Agricultural University.

On 7th November 2019, the 1st steering committee meeting was organized at SPRERI, wherein the progress and further action plan for the proposed activities in the project were discussed.

As most of the farmers that were approached were skeptical about the proposed system, to gain their confidence it was planned to make the solar-biogas hybrid refrigeration system operational again. The system was inspected for the required replacements/ repairs. Initial performance data were generated to check with faults, if any, in working of the VAM (vapor absorption machine), solar thermal and solar PV plant. All the major repair works required and replacements needed are being carried out. Once operational, a workshop will be organized to demonstrate the system to farmers.

1.9 Regional Test Centre

On 21st May, a surprise BIS surveillance visit was carried out by Mr. Manish Raja (Sci. C, BIS Mumbai) and completed without any non-conformity or major observations.

In the month of June, MNRE informed that financial support to all the RTC's is being discontinued from April 2019. SPRERI decided to explore other funding sources to run the RTC facility. On 31st July a business meet was organized at SPRERI, 17 participants from 10 manufacturing companies and one solar energy consultant from Pune attended the meeting to assess the manufacturers requirements & to explore supporting RTC activities at SPRERI. The response from the manufacturers of solar water heaters, testing of flat plate collector and solar box cooker was not favorable, hence decision to discontinue the testing facility was made until further fund is arranged. Details on number of samples received and tested during this year are given in Table 2.

Table 2 Statement of devices received and tested during the year (April 19 to March 20)

Devices	Received for testing (Units)	Testing completed (Units)*
Flat plate collectors	00	06
ETC/FPC based solar water heating systems	06	05
Reflective sheets	03	03
Total	**09**	**14**

* Includes few devices which were received during the previous year

2.1 Gaseous & Solid bio-fuel

Bio-methanation of wet organic fraction of municipal solid waste (MSW) to useful energy fuels

To add value to MSW projects, SPRERI has initiated working on converting the wet organic fraction of MSW to methane rich bio-gas using SPRERI's patented technology. MSW was collected from a local dump yard. The mixed waste contained plastics (20%), glass (5%), dry leaves (30%), wet waste (40%) and inert material (3%) etc. Glass and other inert material were removed manually. Approximately 70% volatiles in the form of organic leachate from MSW was extracted by mechanical pre-treatment.

To convert the wet organic fraction of MSW into bio-gas, three laboratory-scale anaerobic hybrid reactors (AHR) of same size and volume were fabricated with necessary accessories. The reactors were named as R_1, R_2 and R_3. Natural (Gravel & Pumice stone) and synthetic (Polypropylene saddles) packing media with voidage of 55, 51 and 93% and bulk density of 1410, 343 and 82.13 kg m^{-3}, respectively were used as fixed film support. The reactors were operated at 10 to 5 d hydraulic retention time (HRT). The leachate chemical oxygen demand (COD) was in the range of 30-35 g L^{-1}. Inlet COD maintained was 5 g L^{-1}. Maximum bio-gas production rate was in R_2 (34.7 L d^{-1}), followed by R_3 (28.4 L d^{-1}) and R_1 (26.3 L d^{-1}), respectively. The pH and volatile fatty acid: alkalinity ratio remained within the stability range. COD removal was 68-75% and methane content was 65-75%. The total solids and volatile solids in the outlet were found to be almost same with HRT up to 5 d.

Pelletization

Densified biomass, especially pellets has drawn the global attention due to its advantage over raw biomass with its physical and combustion characteristics. With this backdrop, different agro-residual crops viz. banana stem, rice straw, cotton stalk, groundnut shell and leaf litter waste were tried to produce 6, 8 and 10 mm pellets to test in cook stove/boiler for domestic/ industrial uses for better combustion (Fig. 12). Initially, the pre-treatment i.e., drying, cutting of the selected biomasses was done. The powered biomass was then characterized for its compositional, ultimate and proximate analysis using standard protocols. Pellets were produced using commercially available 60 kg h^{-1} capacity rotary drum type pelletizer.

Fig.12 Fuel pellets from different biomass

The pellets produced were tested for thermal efficiency of systems using a forced-draft domestic size cookstove. Thermal efficiency was found to be in the range of 30-44%. Calorific value (CV) of pellets the produced was in the range of 3136-4404 kcal kg^{-1}. Preliminary production cost of the pellets was also carried out for banana stem, rice straw, cotton stalk and groundnut shell and found to be in the range of Rs. 8 to 9 per kg of pellets.

2.2 Liquid bio-fuel

Low cost cellulases

In-expensive black liquor generated during mild alkali pre-treatment was evaluated as a moistening agent to produce cost effective hydrolytic enzymes using novel cellulo-xylano fungal strain i.e., *Aspergillus tubingensis* M7 isolated from termite guts (Fig. 13). Central composite design with four factors viz. incubation period, inoculum size, moisture content and nitrogen concentration and five different levels covering factorial points (-1, +1), axial point (-α, +α) and central point (0), in which the value of α is 2.00 were tried to optimize culture conditions for four hydrolytic enzymes. The fungus competently produced 21.90 and 22.46 FP activity, 1004 and 1369 endoglucanase, 117 and 142 β-glucosidase and 8188 and 7981 U g^{-1} xylanase activity by using black liquor and synthetic medium, respectively. The crude hydrolytic enzymes from black liquor were evaluated for saccharification of pre-treated biomass at 50°C. Reducing sugar yields (mg g^{-1} substrate) and the corresponding saccharification efficiency (%) from rice straw, corncob, sugarcane bagasse and banana stem were 745.50 (86.02; 18 h); 596 (74.50; 24 h); 358.15 (42.98; 24 h) and 245.70 (33.00; 24 h), respectively. Untreated, pre-treated, and residual biomass after enzymatic hydrolysis was studied for its pyro-kinetic behaviors. Residual biomass compositional analysis revealed that reduced onset temperature, decreased activation energy and pre-exponential factor in saccharified biomass as compared to pre-treated and untreated biomass, makes it suitable for its utilization for pyrolysis to obtain value-added products.

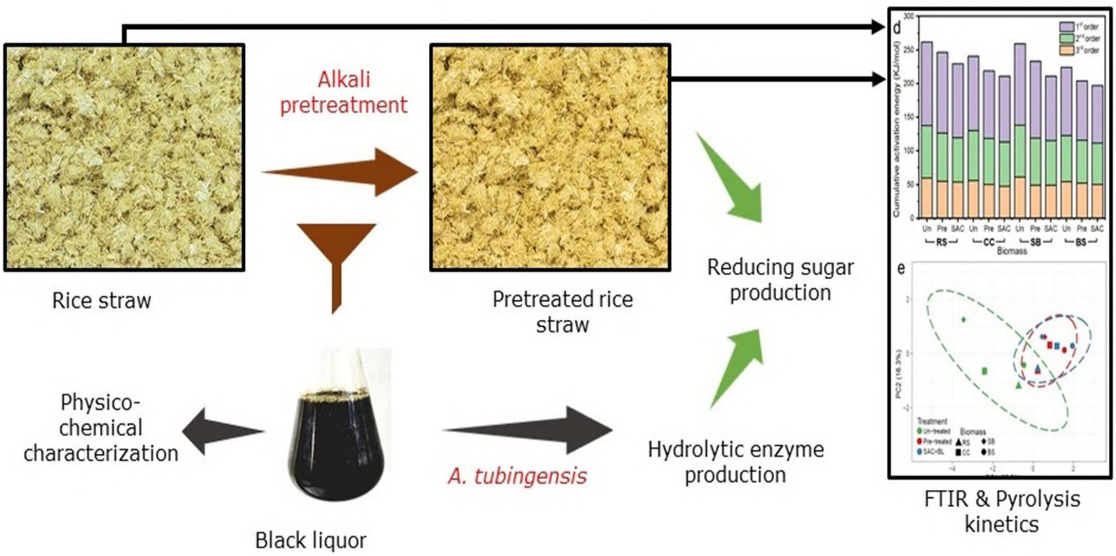

Fig.13 Production of hydrolytic enzymes from black liquor and subsequent utilization for fermentable sugar production

Pre-treatment using green solvents

Green solvents synthesized were applied for the pre-treatment of lignocellulosic biomass i.e., rice straw. Post pre-treatment, solid material was subjected to recovery of ethanol and silica while liquid portion underwent downstream processing for extraction of lignin and xylan. Techno-economic analysis (TEA) of the developed green solvent based process was carried out considering the base case as 3.45 kg d^{-1} and projected case as 1 tonne d^{-1}. Under conventional set-up, agro-residue was converted to ethanol via NADES based pre-treatment followed by saccharification and fermentation. While, multi product bio-refinery involves pre-treatment followed by downstream processing for deriving value-added products viz. cellulose, lignin, xylan and silica, respectively. This also involves recycling and reuse of green solvents.

TEA was performed using the '*nth plant*' economics considering all the capital and operational expenditures and returns in the form of revenue generated from different products. Sustainability of the studied cases was based on internal rate of return (IRR), net present value (NPV) and payback period. Fig. 15 summarizes CapEx and OpEx break-up of base case 1.0 and 2.0.

In the projected case for conventional biorefinery, maximum share of CapEx is contributed from Major Equipment Case (MEC). However, in multi-product biorefinery case, contribution of MEC is less due to absence of major cost incurring processes *viz.* enzymatic saccharification and fermentation (Fig. 14). Among the projected scenario, single product bio-refinery was not found feasible owing to negative NPV while the multi product bio-refinery had positive NPV with payback period of ~8 y and IRR of 22%.

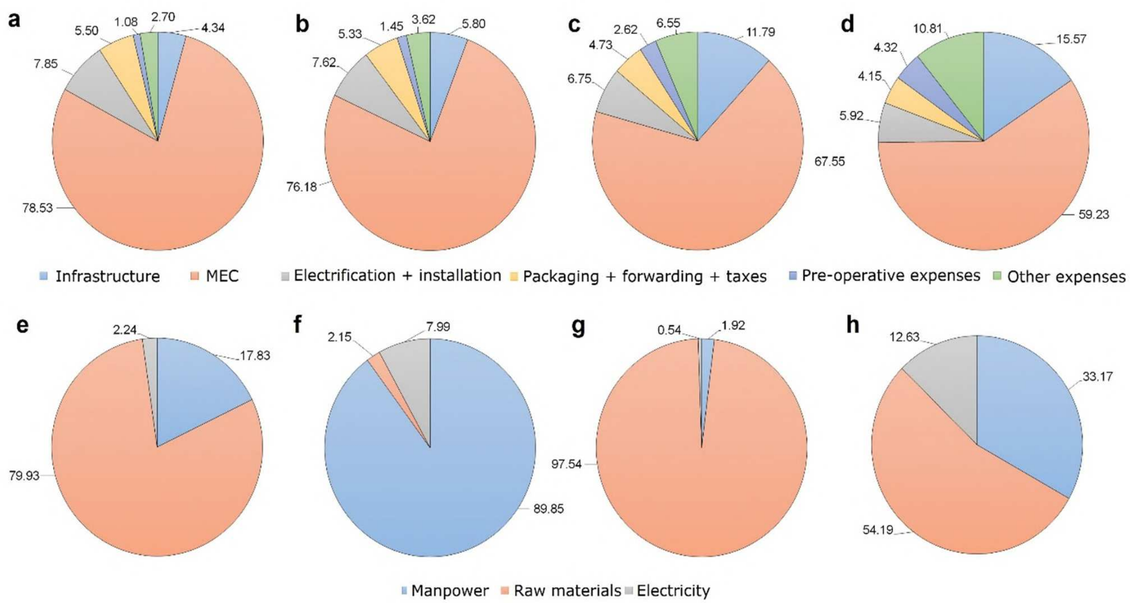

Fig. 14 (a, b) summarizes CapEx and OpEx break-up of base case & projected case 1.0 and 2.0

Micro-algae cultivation and harvesting for bio-diesel production

Vertical tubular photobioreactor was designed, developed and installed at the Algal Research Station, SPRERI (Fig. 15a). The total volume of the photobioreactor is 75 L. Cultivation of micro-algae was performed in vertical tubular photobioreactor for 7 days in commercial media as well as raw dairy waste water (RDW). Results were found to be similar to bench scale results with tris acetate phosphate (TAP) and RDW yielding 1.6±0.2 and 1.5±0.4 g L^{-1} micro-algae, respectively. Lipid (%) was found to be 25.6±0.74 and 26.2±0.90 in TAP media and RDW, respectively.

Fig. 15 (a) Vertical tubular photobioreactor
(b) 100 L fractional distillation unit

After microwave pre-treatment, preliminary lipid extraction was performed using soxhlet apparatus and different solvents viz. hexane, chloroform, chloroform: methanol (1:1), diethyl ether, petroleum ether and isopropyl alcohol were tested for maximum efficiency. Maximum lipid extraction efficiency (%) was found in chloroform (28) followed by chloroform:methanol (25), hexane (25), petroleum ether (23), isopropyl alcohol (20) and diethyl ether (19). Lipid extraction using chloroform:methanol (1:1) as solvent has yielded 23±0.81% lipid in pilot-scale fractional distillation unit installed at SPRERI (Fig. 15b).

2.3 Value-added by-products

Bio-lignin nano-particle synthesis from lignocellulosic waste using green solvents

Different agro-residues viz. rice straw, wheat straw, sawdust, cotton stalk and sugarcane baggase after size reduction were selected for extraction of lignin using green solvents. They were pre-treated using lactic acid and choline chloride mixture at 121°C for 60 min. Post- pre-treatment, the black liquor was precipitated through water dilution method. Precipitated lignin was separated by membrane filtration and dried till moisture content reached <5% (w/w).

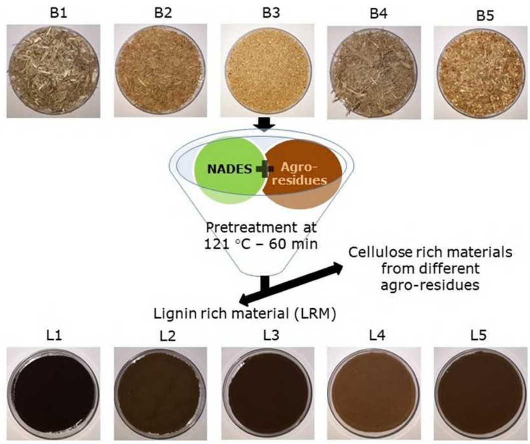

Fig.16 Biomass (B) selected for lignin extraction (L): cotton stalk (B1, L1), rice straw (B2, L2), sawdust (B3, L3), sugarcane baggase (B4, L4)

Solubility of the extracted lignin was tested in around 10 different solvents viz. acetone, ethylene glycol, DMSO, THF, pyridine, IPA, methanol, chloroform, acetone+water, IPA+water etc. for nano-particle synthesis. The order of solubility of lignin in different solvents was found to be DMSO>THF>ethylene glycol>pyridine> acetone+water. Lignin nano-particles were synthesized through dialysis method, and the size of nano-particles obtained was ~145 nm. Further investigations are being performed to bring down the size of nanoparticles to <100 nm. Fig. 16 shows the methodology for lignin extraction using different biomass selected for the study, lignin obtained after pre-treatment and different methods being investigated for nano-particle synthesis.

Conversion of sheep wool to usable products

India is rich in sheep biodiversity. Patanwadi, Marwari and Dumba are three important breeds of Gujarat. Because of the availability of other textile materials, sheep wool unfortunately not in demand and thus income from sheep wool is quality reduced. To provide pastoralists an alternative source of income, SPRERI received a consultancy project from M/s Sahjeevan Trust (NGO), Bhuj to carry out a feasibility study on conversion of Patanwadi sheep wool to bio-manure. Initial trials were carried out at SPRERI for composting of sheep wool. Under such trials, sheep wool was mixed with developed consortia and was incubated for 80-90 days. After the incubation period, the material though softened, was found not completely converted into the desired product i.e., manure. In addition to composting, simultaneous studies were also carried out to investigate other potential uses of sheep wool protein to value-added products. In this study, sheep wool protein was dissolved using alkali method and was characterized using various spectrophotometric and molecular techniques. The identified and extracted keratin was thus used to synthesize the nano-fiber by mixing it with the plasticizer. The optimization of protein nano-fiber synthesis was carried out using electrospinning method (Fig. 17). The optimized nano-fibers were visualized in scanning electron microscope, with size in the range of 120-450 nm with smooth surface (Fig. 18).

Fig.17 Nano-fibers (a) PVA (12%)-Control; (b) PVA (12%) + protein (20%)

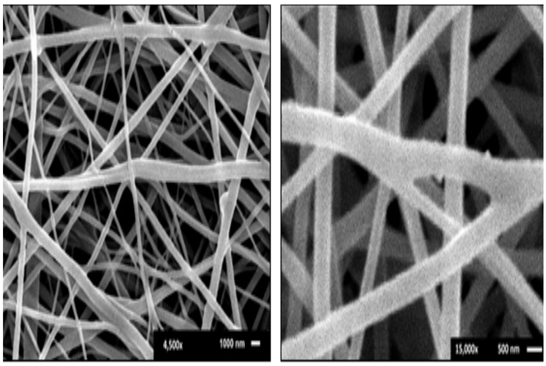

Fig.18 SEM images of nano-fibers (a) PVA (12%)-Control; (b) PVA (12%) + protein (20%)

3.1 Gasification

Introduction of SPRERITECH fluidized bed gasification system in Poha making industries for improved efficiency and working environment

Gujarat is an agriculturally rich state. Several districts of Gujarat have Poha making industries and many of these industries are currently using wood and sawdust as a fuel for roasting employing conventional combustion technologies. Such industries are creating environmental pollution because of loose biomass burning, which is an age old and inefficient process. The operators of these industries are also liable to suffer because of many respiratory problems. To circumvent the problem faced by these industries, a fluidized bed gasifier (FBG) can be installed. In particular, the team members visited the Swastik Poha Industry, Umreth plant and have initiated a plan to install a FBG.

SPRERI has already designed and developed a pilot-scale FBG (30-35 kg h^{-1} capacity) for thermal applications. It can utilize loose/powdered biomass for production of producer gas; which in-turn can be used for thermal energy generation. To reduce the suspended particulate matter content in the producer gas, cyclone separators are designed and provided along with the system. The performance of the fluidized bed reactor has been experimentally evaluated using rice husk and sawdust as feedstock. This system was further scaled-up to 100 kg h^{-1} capacity for gasification of sawdust.

Long-run trial experiments with sawdust (2 mm particle size) were carried out at 70-75 kg h^{-1} feeding rate for a duration of 13 h. During this experiment, a regular and constant temperature profile was observed. Temperatures at five different points along with flame temperature (flame core using IR probe) were recorded at regular intervals and the average temperature profile is reported. Among these, six different temperatures, profile for three temperatures i.e., bed, gas temperature at the outlet of reactor and flame temperature were compared (Fig. 19).

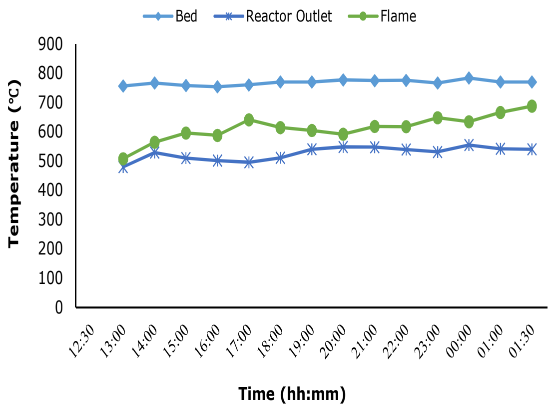

Fig.19 Time-based temperature profile of the system during long duration trial

In addition, repetitive trials of 8 h duration were carried out to observe the stability of the system and to check the reproducibility. At present experiments are under progress to observe the effect of increasing particle size of the feed (from 2 mm to 4 mm), long duration trials (~20 h) using both feed to understand the maintenance cycle. With this the system can be installed at Poha production units. Installation of FBG in Poha industries will provide a clean energy solution to these industries. It will also improve the working environment by reducing environmental pollution.

3.2 Pyrolysis

A continuous pilot-scale intermediate pyrolysis based bio-refinery

The Indian timber market is growing rapidly. The timber industry is a major source of sawdust since it is generated in large quantities during wood processing. As per data reported by the American Hardwood Export Council, in 2016, there were ~23,000 sawmills in India and on an average each saw mill generates ~822.4 tonnes of sawdust annually. An analyses of this data shows that annually ~18.91 million tonnes of sawdust is produced in India. Substantial amount of sawdust is used in thermal industries as fuel during combustion processes to produce thermal energy. Nevertheless, this causes significant risks to the environment and eventually to human health (Fig. 20). Approximately, ~5.5 million tonnes of surplus sawdust is produced annually in India.

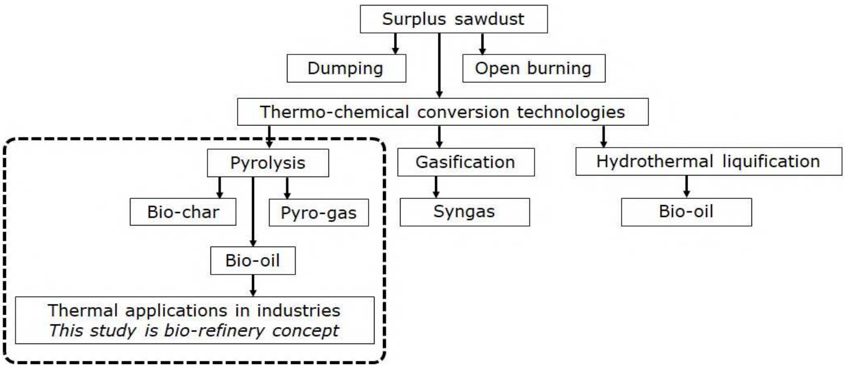

Fig.20 Towards a pyrolysis based bio-refinery for production of bio-oil and bio-char from sawdust

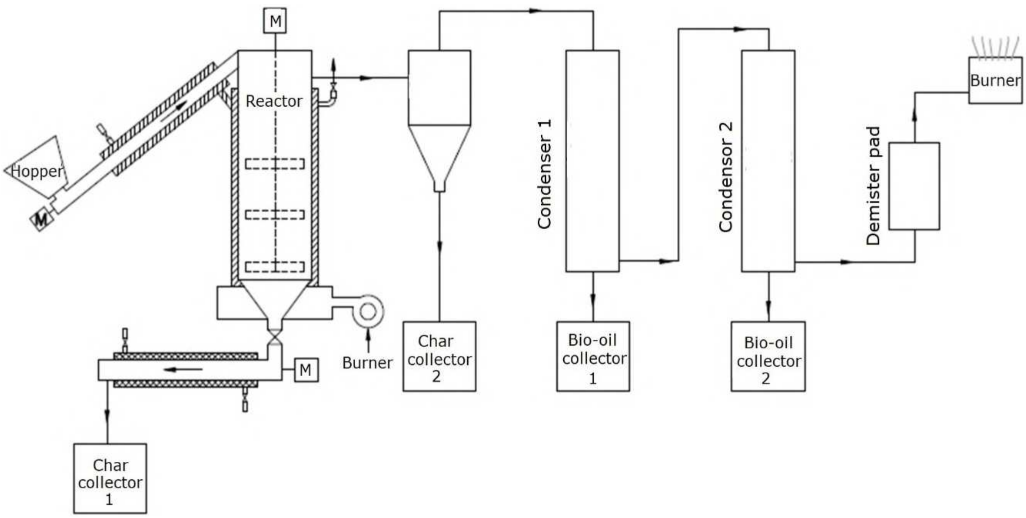

Fig.21 Schematic arrangement of SPRERITECH continuous pyrolysis reactor system

In the above context, SPRERI has designed and developed a vertical moving bed type pyrolysis reactor (Fig. 21). Using the SPRERITECH continuous pyrolysis system different biomass can be pyrolyzed. This process yielded bio-oil, pyro-gas and bio-char. After obtaining the liquid phase bio-oil is separated from it via gravity separation. The bio-oil in the remaining aqueous phase is recovered by extraction using organic solvent(s).

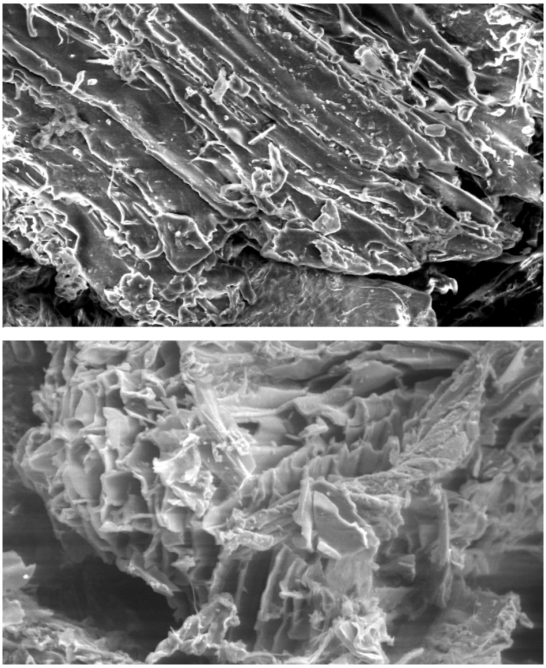

Fig.22 SEM images (1500x magnification) of sawdust (a) and sawdust bio-char (b)

Experiments were carried out in both batch pyrolysis and continuous pyrolysis system. It was found that in similar reaction conditions, in comparison with the batch pyrolysis, 6.15 wt% more bio-oil yield was obtained during continuous pyrolysis. After separation and isolation of the bio-oil, its CV and physico-chemical characterization were carried out. In addition, it was subjected to NMR, FT-IR and GC-MS analyses. The bio-oil was found to contain various different classes of compounds including acids, alcohols, aldehydes, ketones, phenols, furans and aromatics among others.

Moisture content, ash content, volatile matter, fixed carbon, CV and bulk density of bio-char was characterized Furthermore, both raw sawdust and bio-char were analyzed using SEM (Fig. 22). It can be clearly seen that in the SEM image of bio-char, there are holes created on its surface during pyrolysis process of sawdust (Fig. 22). This is because of evolvement of volatile matters out of the biomass during the process of thermal degradation.

Fast pyrolysis

As discussed in the previous sections, pyrolysis is a promising thermo-chemical conversion technology which occurs via thermal degradation of carbonaceous material leading to production of bio-oil, bio-char and pyro-gas. More recently, fast pyrolysis is

Fig.23 Schematic arrangement of the SPRERITECH fast pyrolysis system

recognized as a technology for converting biomass into liquid biofuel and works with a heating rate (1000°C s^{-1}), temperature range (450-650°C) and residence time (<2 s). As a result, the biomass quickly decomposes into pyro-vapor and solid residue called bio-char. Part of the resulting vapour is condensed to form bio-oil. This is a suitable technology to obtain high yield of bio-oil. At SPRERI, fast pyrolysis of sawdust was performed using a fluidized bed reactor designed and developed in-house at the TCC division (Fig. 23). By using this technology, sawdust is converted into bio-oil, bio-char, and non-condensable gases. The generated products are of significance importance as these can be used as fuel or as raw materials in different chemical and life sciences industries. The experiments were performed at 3 kg h^{-1} feeding rate.

Optimum bio-oil yield was achieved at 550°C and at equivalence ratio of 0.20. The obtained bio-oil was characterized using different analytical techniques. During fast pyrolysis of sawdust, different products, bio-oil (~38 wt.%), bio-char (~12 wt.%) and pyro-gas (~50 wt.%) were obtained without using a catalyst. Whereas using zeolite as a catalyst, the bio-oil, bio-char and pyro-gas yields were ~44 wt.%, ~4 wt.% and ~52 wt.%, respectively; this is expected to improve further. ^{1}H NMR analysis confirms highest assignment for aromatic hydrocarbons, alcohols, and aliphatic proton. Additionally, ^{13}C NMR analysis indicates that highest carbon assignment for aromatic and olefin compounds. FT-IR result reveals the presence of hydrocarbons, alcohol, phenols, and aldehydes among other compounds in bio-oil. GC-MS analysis of bio-oil shows the presence of several oxygenated organic compounds in bio-oil. Pyro-gas analysis confirms that it is a mixture of N_2, CO, CO_2, H_2, O_2, and CH_4. Further experiments using different agro-residues available in Gujarat, such as, groundnut shell and cotton stalk are currently under progress.

3.3 Combustion

Refinement of bio-oil based burner for thermal application

A bio-oil burner assembly has been developed at SPRERI (Fig. 24). The set-up consists of oil reservoir to store the bio-oil, strainer filter, pump and a fuel burner. bio-oil temperature was maintained at ~70°C and pressure was maintained as required. In our previous study, the pre-heating of the oil

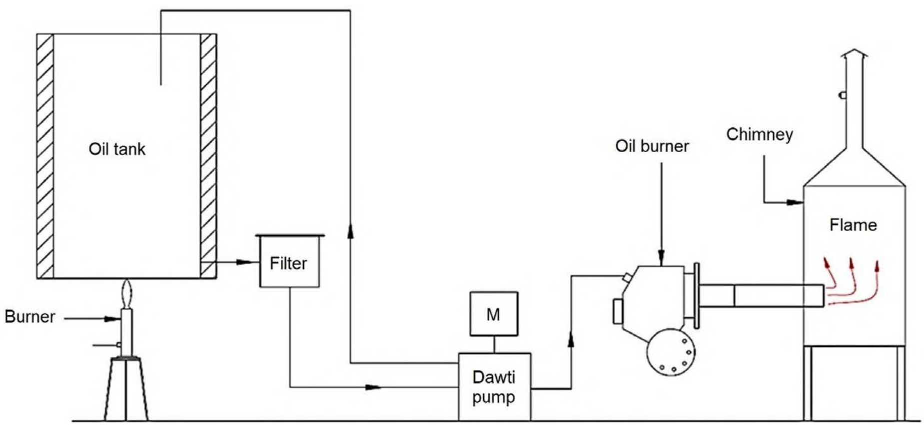

Fig. 24 A bio-oil based burner developed at SPRERI

was carried out in a separate fuel tank (1 L); hence, the desirable and uniform heating was difficult to achieve. While during this study, to have uniform heating, the oil tank was properly insulated before heating. In addition, the burner was integrated with a combustion chamber and a stack line was given for emission measurement. The burner ran satisfactorily for 6 h and flame temperature was found to be 750-800°C.

In addition, blending studies were carried out. During the blending experiments, it was observed that only 2% bio-oil can be used as a blend with furnace oil. Addition of more than 2% bio-oil to furnace oil is causes insolubility and creates an emulsion. Bio-oil was also blended with waste cooking oil in different proportions. Even with the naked eye, it was seen that 0.5% bio-oil has not mixed well with the waste cooking oil, suggesting that it cannot be utilized as a blend.

3.4 Value-added products from agro-residues

Production of activated carbon from groundnut shell (GNS)

The term activated carbon (AC) is referred to carbonaceous substance with high mechanical strength, high porosity, high adsorptive capacity, surface reactivity with high surface area. It is generally an amorphous microcrystalline, tasteless, non-graphite form of carbon and a black solid substance which resembles powder or granular charcoal. AC cannot be characterized by any distinguishing chemical formula. On the basis of its physical properties, AC can be categorized into numerous classifications; powdered activated carbon, granulated activated carbon, extracted activated carbon, and pellet activated carbon. AC is possibly the most general adsorbent which is commercially employed so far for removal of pollutants from air and water.

In the above context, agricultural residues can be converted into AC through thermo-chemical treatment with or without the uses of activating agents. There are two different processes for AC preparation: chemical treatment and physical treatment. Both processes produce ACs with different shapes and sizes. In physical treatment, the precursor is first carbonized and then undergo as activation using steam or CO_2. In general, physical activation involves two steps; carbonization and activation. However, during chemical treatment precursor is impregnated with an activating reagent; and subsequently, heated under inert atmosphere. The activating reagents dissolve the cellulosic components of the precursor and promote formation of crosslinks. The chemical activation process has many advantages over physical activation as it needs lower temperature, produces high yield; higher surface area of AC and it involves only a single step.

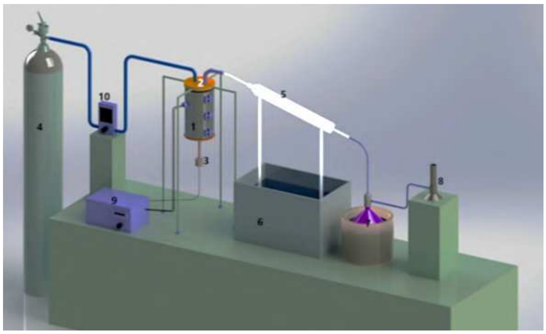

Fig.25 A set-up used for the preparation of activated carbon at SPRERI. 1. Heater 2. Reactor 3. Thermocouple 4. Nitrogen cylinder 5. Glass condenser 6. Cooling water storage tank 7. Condensate collector 8. Burner

Thus far, several studies have been reported for AC production from different agro residues. In this context, Gujarat being one of the largest producers of groundnut a huge quantity of GNS is generated annually. Along this line, GNS can be valorized for the production of high value products. Therefore, in this study GNS was converted to ACs using H_3PO_4, $ZnCl_2$ and KOH as activating agents. For the devolatization process, an in-house developed bench scale reactor was used for the study (Fig. 25).

The AC sample using KOH gave the highest BET surface area (691.69 m^2 gm^{-1}) (Table 3). Synthesized AC samples were also used for determination of methylene blue number (MB_n). For AC sample obtained using KOH the MB_n was 332.20 mg g^{-1}; which is higher than MB_n of AC sample obtained using H_3PO_4 (270.20 mg g^{-1}) and AC sample prepared using $ZnCl_2$ (291.20 mg g^{-1}) (Table 3). The process described here is important from the point of view of waste management and circular economy for a country like India which produces huge quantities of GNS annually.

Table 3 Surface area and MB_n for GNS, GNS char ACs prepared from GNS using $ZnCl_2$, H_3PO_4 and KOH

S. No.	Sample	Surface area (m^2 gm^{-1})	MB_n (mg g^{-1})
1	GNS	1.51	154.4
2	GNS char	3.02	211.8
3	AC produced from GNS using $ZnCl_2$	512.15	291.20
4	AC produced from GNS using H_3PO_4	56.78	270.20
5	AC produced from GNS using KOH	691.69	332.20

4.1 Rural Development Programme

A. SPRERITECH improved biomass cookstove (IBCS)

Field-implementation in Gujarat

Demonstration-cum-awareness programmes for domestic cookstove were organized in Chhota Udepur and Mahisagar districts for villagers and self-help group (SHG) members (Fig. 26). Around 50 villagers took part in both the demonstrations. District livelihood manager (DLM) and other National rural livelihoods mission (NRLM) officials were also present and actively interacted with SPRERI staff.

Following the proper mechanism of documentation on beneficiaries, 300 domestic IBCS have been distributed in 8 villages of Anand districts. Impact study on post implementation of the cookstove is under progress. A few other demonstrations were carried out at SPRERI, where villagers from Morbi and Valsad district have shown an interest in adopting SPRERI's developed IBCS for a clean kitchen environment.

Fig.26 Demonstration of SPRERITECH IBCS

Field-implementation in Jharkhand

1000 nos. of family size natural-draft cookstoves (190-NDS-L) were installed/ distributed in the four districts (Dumka, Godda, Pakur, Sahebganj) of Jharkhand (Fig. 27).

Fig.27 SPRERITECH IBCS use by villagers in Jharkhand

A pre- and post-implementation survey was conducted to measure the socio-economic impact on the tribal populace. The main outputs of the implementation survey are: (1) Time for cooking was reduced by ~25% (5-6 kg d^{-1}) when cooked on IBCS compared to the conventional C-type cookstove. (2) Wood consumption was reduced by 40% compared to the C-type chulha. It has eventually reduced their drudgery in fuel wood collection. (3) Working conditions have improved substantially due to virtually no smoke compared to the C-type chulha. (4) No irritation in eyes during cooking on an IBCS. (5) Extra revenue generation was observed as the family can now sell the saved fuel wood at Rs. 2-3 kg^{-1} in the market.

Other estimated financial and environmental benefits of the introduction of IBCS over C-type chulha in the JTDS project based on data collected during survey (Table 4).

Table 4 Estimated financial and environmental benefits

1	Average family size	5 members
2	Average wood consumption with C-type chulhas	16 kg
3	Average wood consumption in IBCS	9.5 kg
Financial benefits*		
1	Cost of wood in the market	Rs. 3.00 / kg
2	Annual saving in wood	Rs. 7020 per hh
Environmental benefits		
1	Wood saved per day	6.50 kg
2	Annual wood saving	2.37 tonnes per hh
3	Annual CO_2 emission mitigated	4.34 tonnes per hh

* Only for those beneficiaries who are purchasing wood for fuel

Income-generation activities

To address the need for initiating income-generation activities at the village level, SPRERI on understanding the energy requirements through surveys for various activities i.e., tribal school, nashta house, pakora making centers, dhabha etc., designed and developed a dhabha-size IBCS of 4.75 kW_{th} capacity. Post fabrication, the demo piece was installed at Anudanit Nivasi Primary School at Siyad, Devadtal village for field testing with a 6Vx 2, 1.2 Ah battery with the system (including a regulator) to ensure continuous operation of the cookstove during power outages particularly for the mid-day meal scheme. Data collection is under progress. A comparative study has been carried out to evaluate reduction in wood consumption and in the time saved for boiling water and cooking food (Table 5). The beneficiary is using the dhabha-size IBCS on a regular basis.

Table 5 Comparative analysis of cooking on conventional cookstove and dhabha-size IBCS

Parameters	Conventional cookstove	Dhabha-size IBCS	Saving (%)
Water boiling (12 L)			
Time (min)	55	39	29.0
Wood consumption (kg)	1.40	1.00	28.6
Rice cooking (1 kg)			
Time (min)	27	25	10.0
Wood consumption (kg)	1.0	0.9	10.0
Dal cooking (0.50 kg)			
Time (min)	56	38	32.0
Wood consumption (kg)	2.0	1.4	31.0
Potato boiling (1 kg)			
Time (min)	43	28	34.9
Wood consumption (kg)	1.4	1.1	21.4

Fig.28 Demonstration and explaining the benefits of dhabha size IBCS to DLM and SHG-member

Demonstration and field testing of dhabha size IBCS was also conducted at Rural Nashta House at village Jhand Hanuman, Dist. Chhota Udepur. DLM-Chhota Udepur, Taluka level livelihood officials & village level coordinators along with respective Sarpanch and about 35 women members of different SHG's from nearby villages were present to see the live demo (Fig. 28).

With the objective of evaluating its performance on regular use and to assess how much improvement in income can be made in an SHG-field testing was carried out for 30 days at Maruti Restaurant (run by an SHG) near Jhand Hanuman Temple at Village Jambugoda in Chhota Udepur district. The system has brought substantial improvement in the cooking time and also in the saving potential on consumption of wood on a daily basis.

B. R&D activities of IBCS

Improvement in IBCS for increased shelf-life

With the objective of increasing the shelf-life of the SPRERITECH domestic IBCS, an improvement in IBCS was made with the provision of special enamel coating (Fig. 29). 500 h of rigorous in-house testing to measure the longevity of the coating was carried out. No physical deformation on the surface was detected during the long-run testing.

Development of double-pot IBCS with chimney

To meet multi-cooking and hot water requirements at village level, and to improve the indoor air quality of the household, SPRERI after obtaining feedback at village level, has developed a double-pot IBCS with chimney (Fig. 30). The developed cookstove was tested at SPRERI's test facility for various parameters i.e., indoor air emissions and efficiency of overall system etc.

Fig. 29 & 30 SPRERITECH domestic IBCS & Double pot cookstove

SPRERI's side feeding IBCS domestic cook stove was used with and without chimney in the study. For monitoring the indoor air quality a portable instrument i.e., TSI make DustTrak-II and a gas analyzer were used to collect the comprehensive data. Each stove was subjected to a water boiling test using 12-liter water. Water boiling test procedures were followed to evaluate in the laboratory also. The results are summarized in Table 6.

Table 6 Mean concentrations of pollutants PM, CO and thermal efficiency

Stove type	$PM_{2.5}$ ($mg\ m^{-3}$)	PM_{10} ($mg\ m^{-3}$)	TPM		CO		Efficiency (%)
			$mg\ m^{-3}$	reduction (%)	$mg\ m^{-3}$	reduction (%)	
Without chimney	0.556	0.578	0.66	-	5.77	-	26.11
With chimney	0.207	0.238	0.24	63	1.50	74	23.90

C. Introduction of RE gadgets

Improving the harvesting of natural day-light

Many villagers in Gujarat being unskilled workers and having a low-income i.e., Rs 3000-7000 per month still cannot afford to have reliable grid-connected electricity in their homes. To meet their lighting loads during daytime and during the night, SPRERI has adopted a solar micro dome (SMD). It is a product developed by NBIRT Kolkata, and has been installed in 3 villages viz. Munjkuwa, Isnav, and Devadtal to observe the acceptability of the product (Fig. 31). Performance monitoring of the SMD is in progress.

Fig. 31 Solar micro dome installed at Devadtal village

Implementation of toilet-linked solid-state bio-gas plants

New implementations

Under the umbrella of rural development activities, SPRERI has also installed two family size solid-state toilet-linked bio-gas plants at selected farmer's sites in Ganpatpura (2 m^3 d^{-1} capacity) and Shokhda (6 m^3 d^{-1} capacity) villages of Anand and Vadodara districts, respectively. Base-line data were collected from the users.

Technical support to existing running plants and re-starting of defunct bio-gas plants

In order to evaluate the performance of earlier installed 52 Nos. family size bio-gas plants, feedback was collected and appropriate technical guidance was provided to the beneficiaries to improve the performance of the existing bio-gas plants. (Fig. 32). Also, complete techno-social support was extended to 12 non- functional plants to make them operational **by SPRERI's team at village** Shokhda, Ajod, and Munjkuva.

Fig. 32 Construction of solid-state bio-gas plant

Drying of fruits and vegetables in agro industries through the solar tunnel dryer (walk-in type)

To reduce the drying time and to increase the production capacity, a walk-in type solar tunnel dryer of 100 kg capacity was set up at M/s Geo-fresh Organic, Sidhpur (Gujarat). It was implemented to dry moringa and papaya leaves used for medicinal therapies (Fig. 33).

Fig.33 Moringa leaves drying in open sun and walk-in type solar tunnel dryer at M/s Geo-Fresh Organic, Sidhpur

Comparative data of the open sun-drying and drying using solar tunnel dryer is shown in Table 7 below:

Table 7 Drying time of products in open-sun and under solar tunnel dryer

S. No.	Agri-produce	Batch quantity (kg)	Drying time	
			Open sun drying	Walk-in type solar tunnel dryer
1	Moringa leaves	100	11-12 h	5-6 h
2	Beet leaves	100	6-7 d	3 d
3	Papaya leaves	100	15-16 h	7 h

The dried products through solar tunnel dryer were also evaluated in terms of odor, texture, and micro-nutrients contents. They were found to have retained better quality and in turn, were proved to be highly economical. A comparative analysis of its color retention properties has been made for the dried leaves. The lab results are depicted in Table 8.

Table 8 Lab results of moringa and papaya leaves

S. No.	Sample name	Crude fiber (%)	Color value		
			L	a	b
1	Open sun drying papaya leaves	11.7	41.8	-5.2	19.3
2	Solar dryer papaya leaves	11.69	41.6	-6	19.9
3	Open sun drying moringa leaves	8.6	44.5	-5.8	22.1
4	Solar dryer moringa leaves	8.3	40.9	-5.9	22.2

From the results, we can see that the lightness of the color (L Value) is on the scale towards the black side as it has undergone the drying process. On neutral grey scale reading, the solar tunnel dried leaves show a higher green pigment color than the open sun drying, also on the yellow scale of the spectrum. Hence the color is retained much better in solar tunnel drying than open sun drying. The lowered crude fiber percentage in solar tunnel drying can be due to an increase in temperature.

M/s Geo-Fresh Organic is satisfied with the improvement in the quality of the dried products and reduction in drying time leading to higher production rates. This has prompted them to go for another solar tunnel dryer. The appreciation letter on SPRERI's efforts and guidance in setting-up of solar tunnel dryer for M/s Geo-fresh is annexed in recognitions.

4.2 Municipal solid waste management

Survey of commercial units (Restaurants, hotels, eateries etc.) in Anand, Vallabh Vidyanagar, and Karamsad

The Department of Biotechnology, Government of India has supported a project under clean energy scheme for setting up a 3.5 TPD capacity wet organic fraction from MSW bio-gas plant. The pilot plant will be set-up at the site provided by Charotar Arogya Mandal, Karamsad. The project will also address creating a mechanism to segregate the waste at source, collection, and transportation to the plant site. In this regard, a detailed market survey was conducted. During the data collection, around 239 eateries e.g., hotel, restaurant, nashta centre, street stall, hand cart, dhabha, dining hall, mess, bakery, café, hostel canteens were surveyed in Vallabh Vidyanagar, Anand and Karamsad area.

In the survey, it was found that around 88% of the units prepare vegetarian food and the balance 12% are involved in both veg and non-veg food preparation. A mix of eateries were found during the survey i.e., ~56% hotels and restaurants, 20% nasta centers, 13% any other i.e., juice centre, chinese eatery, bakery, tiffin services etc. The organic waste being generated at these 239 eateries is:

Table 9 Composition of organic waste generated

Details	Weekdays quantity (kg d^{-1})
Cooked wet waste	1115 (90)
Uncooked wet waste	542 (72)
Liquid waste	61 (72)
Total organic waste per day	**1718**

* *In ( ) is no. of respondent*

The weekend's quantity is less as a few of the eateries have not shared the data. Apart from wet organic fractions, around 71 eateries were found generating around 710 kg of dry waste i.e., disposable plates, glasses, paper, empty boxes etc. and ~44 kg segregated plastic waste in a day. The generated waste is either being disposed by owner/staff in the Municipal vehicle and dustbin or gets collected by cattle owners for cattle feed. Apart from the regular disposal, there is one private agency (M/s Maruti Solaris) that collects waste, screens it and sells the recyclable material to a vendor and disposes the balance to the municipal vehicle (Fig. 34).

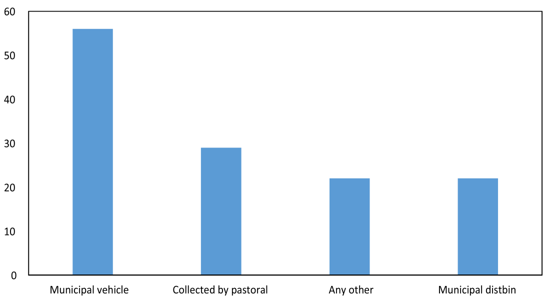

Fig. 34 Disposal practice by eateries (%)

The frequency of collection in the morning and at night are 73, whereas during evening and afternoon are 29 and 11 (Fig. 35). Although 50% of eateries segregate their waste at source, the photos and mix of waste details collected by SPRERI staff shows that much effort is still needed in segregating the mix containing packaging, plastic substances, paper boxes, etc.

Fig. 35 View of waste generation at eateries

Consultancy Projects

- MoU signed between SPRERI and Sahjeevan Trust, Bhuj to conduct feasibility studies on conversion of sheep wool to bio-fertilizer.
- MoU signed between SPRERI and NDDB Dairy Services, New Delhi for construction and commissioning of a cattle dung based bio-gas plant of 125 cu m d^{-1} for power generation at Rahuri semen station, Rahuri, Maharashtra.

Recognitions & Academic Activities

- Dr. Gaurav Mishra was appointed as Co-opt Member, Academic Council of Anand Agriculture University, Anand
- Dr. Gaurav Mishra was appointed as Expert Committee member of Technology Interventions for Addressing Societal Needs (TIASN), SEED Division, DST, New Delhi
- Dr. Gaurav Mishra was appointed as Expert Committee member of Scheme for Young Scientist and Technologists (SYST), SEED Division, DST, New Delhi
- Dr. Gaurav Mishra and Dr. Madhuri Narra were appointed as Member & Associate Member for BIS Solid Mineral Fuels and Solid Biofuels Sectional Committee, PCD 7, New Delhi
- Er. Asim Kumar Joshi was appointed as Member, Bureau of Indian Standards (BIS) - Renewable Energy Sources: MED 04 technical committee

Graduate & Post-graduate dissertations

Student	Mr. Raajdeep Bhalodiya, Mr. Parth Dhanak
Programme	Bachelor of Mechanical Engineering
Institute	BVM Engineering College, Sardar Patel University
Division	Solar Energy Division

Student	Er. Mayank K. Parmar
Programme	Master of Mechanical Engineering
Institute	AD Patel Institute of Technology
Division	Thermo-chemical Conversion Technology Division

Student	Mr. Mithil K. Solanki
Programme	Bachelor of Mechanical Engineering
Institute	BVM Engineering College, Sardar Patel University
Division	Thermo-chemical Conversion Technology Division

Student	Mr. Yash K. Makwana
Programme	Bachelor of Mechanical Engineering
Institute	BVM Engineering College, Sardar Patel University
Division	Thermo-chemical Conversion Technology Division

Patent & Publications

Patent:

- A patent has been filed (Patent No.292125) for "Bio-gas production from enzymatic hydrolysate of rice straw" (Application No. TEMP/E-1/26412/2019/Mum) on June 24, 2019

Publications:

- Madhuri Narra, Darshan Maganlal Rudakiya, Kumud Macwana, Nidhi Patel (2020). Black liquor: A potential moistening agent for production of cost-effective hydrolytic enzymes by a newly isolated cellulo-xylano fungal strain *Aspergillus tubingensis* and its role in higher saccharification efficiency. Bioresource Technology 306; 123149
- Bhavin Soni, Sanjeeb Kumar Karmee (2020). Towards a continuous pilot scale pyrolysis based bio-refinery for production of bio-oil and bio-char from sawdust. Fuel 271; 117570
- Geeta Kumari, Bhavin Soni, Sanjeeb Kumar Karmee (2020). Synthesis of activated carbon from groundnut shell via chemical activation. Journal of the Institution of Engineers (India): Series E, invited article
- Sanjeeb Kumar Karmee, Geeta Kumari, Bhavin Soni (2020). Pilot-scale oxidative fast pyrolysis of sawdust in a fluidized bed reactor: a bio-refinery approach, Bioresource Technology. https://doi.org/10.1016/j.biortech.2020.124071
- Darshan Maganlal Rudakiya, Shriram Hasmukh Patel, Madhuri Narra (2019). Structural insight into the fungal β-glucosidases and their interactions with organics. International Journal of Biological Macromolecules 138; 1019-1028
- Shaishav Sharma, Adepu Kiran Kumar, Gaurav Dixit, Ekta Shah, Aesha Patel (2019). Techno economic analysis (TEA) of micro-algae based dairy effluent treatment using a pilot-scale High Volume V-shape Pond (HVVP) system. Renewable Energy 145; 1620-1632
- Shaishav Sharma, Ekta Shah, Deepti Davla, Aesha Patel, Gaurav Dixit, Adepu Kiran Kumar (2019). Effect of micro-algae based diet on oxidative stress enzymes of African catfish, *Clarias gariepinus*. International Aquatic Research 11; 377-387

Training and Demonstrations

SPRERI conducted a series of **thirty-nine one-day awareness programmes** on “Various aspects of RE Technologies” and “RE Sources and Environment protection” at MGIIRED, Amrol, Dist. Anand for students of Engineering colleges, polytechnic college and ITI, farmers, SHG members under the Gujarat Energy Development Agency (GEDA) funded programme. The objective of the programme was to create awareness among the youth and community about the importance and usefulness of RE.

1773 participants took part in the training programmes during 2019-2020 Table 10. SPRERI’s subject matter Scientists and Engineers provided training on RE technologies through various modes of teaching including power point presentations and field visits to the technology park, RE mobile van and 1 MW solar PV power plant (located at MGIIRED - GEDA center, Amrol) (Fig. 36).

Fig. 36 Views of awareness programme and exposure visit at MGIIRED, Amrol

Table 10 Category wise and gender-wise break-up of number of participants of the training programme

Details of participants	Nos. of training programes	Male	Female
ITI	14	632	24
Diploma	7	253	47
B.E./B.Tech	9	357	30
M.Sc. /M.Tech	1	43	1
Agri. Engg.	1	33	2
Arts and Commerce	1	34	22
Farmers	6	124	171
Total	**39**	**1476**	**297**

Open House

The 12th Open House was held on 14th and 15th February 2020. Dr. Sangita Kasture, Director, DBT, Ministry of Science and Technology, New Delhi was invited as the Chief Guest. The Guests of Honour were Shri Bhikhubhai Patel, Chairman, Charotar Vidya Mandal, Vallabh Vidyanagar, and Shri Dhawalbhai Patel, Managing Trustee, Voluntary Nature Club, Vallabh Vidyanagar. Dr. Gaurav Mishra, Director, SPRERI also shared the stage presenting mementos to the officials. On completion of the inauguration function, the dignitaries went around the research divisions and the respective division heads explained to them that ongoing research work and other functional technologies available in their division (Fig. 37).

Fig. 37 Open House inaugural by Shri Bhikhubhai Patel and Dr. Sangita Kasture

For the first time, a Poster Competition on the theme "INNOVATIVE APPROACHES FOR SOLID WASTE MANAGEMENT" was organized. Engineering students from various colleges participated in the competition and 17 posters were displayed. A separate Jury evaluated the posters. The best three posters were awarded with prizes and certificates (Fig. 38).

Fig. 38 View of students participated in poster competition

Miscellaneous

SPRERI participated in the 2nd Annual Sustainability Fair 2020 held at Dr. Kiran Patel Centre for Sustainable Development, IIT Gandhinagar on February 28, 2020 and International Conference on Rural technology development and delivery organized by Rural Technology Action Group (RuTAG), IIT, Chennai during March 12-14, 2020 and had set-up a stall. The stall comprised posters and models on technologies developed by SPRERI including solar biomass hybrid refrigeration system, solar PV dryer, odourless bio-methanation of fruit and vegetable waste, bio-methanization of dairy effluent, crop residue bio-methanation, biomass combustor, fluidized bed gasifier, improved biomass cookstove and solar micro dome (Fig. 39).

Fig.39 SPRERI stall at IIT- Gandhinagar & IIT-Chennai

SPRERI's role in fighting COVID-19 pandemic

The COVID-19 pandemic was declared a Public Health Emergency of International concern in January 2020, and a pandemic in March 2020. With the rise of the impact of coronavirus in India, the Honourable Prime Minister of India declared a lockdown in the month of March 2020. To combat the virus and its spread, few methods were suggested as the best practices to follow, out of which use of sanitizer as per World Health Organization (WHO) standards was recommended by the WHO. Sudden outbreak of Corona Virus led to a shortage of sanitizers across the country.

SPRERI although being a renowned research institute in the field of RE, took an initiative to support society through the production of sanitizer (as per WHO standards) at their laboratory. In addition to this, SPRERI under the support of DST (SEED Division) also initiated COVID awareness program to improve community awareness on causes, symptoms, and transmission of COVID 19. This awareness program has helped dispel misinformation and myths about the coronavirus pandemic.

Under this program, SPRERI on procuring valid license during strict lockdown period from District Industrial Commission, Nadiad for production of sanitizer, prepared and distributed around 500 litres of sanitizer during initial lockdown period. A dedicated team of scientists followed strict WHO guidelines during the preparation method such as usage of aprons, gloves, masks, and head caps. The team was also involved in bottling, labelling and distribution of the sanitizers (Fig. 40).

Distribution of 500 litres of sanitizer was initiated by SPRERI in various rural areas of Anand, Chotta Udepur, and Khambat region of Gujarat through respective District Livelihood Managers and also targeted mostly the COVID front-line workers such as police personnel, vegetable vendors, and local municipal karamcharis. Along with sanitizer SPRERI also distributed 3000 face masks stitched through women SHG members.

Efforts on creating awareness among the public regarding COVID-19 and the role of SPRERI and DST together towards the fight against COVID-19 pandemic was also made through different press notes (Back Cover Page).

Fig.40 SPRERI team in sanitizer preparation as per WHO guidelines

Conferences, Workshops & Meetings

Conferences

International Conference

S. No.	Details of the programme	Date	Scientist/ Research staff/ Student
1	2nd International Conference on Rural technology development and delivery organized by Rural Technology Action Group (RuTAG), IIT, Chennai Delivered a lecture on "Renewable energy technologies and policies for rural sector"	March 12-14, 2020	Dr. Madhuri Narra

National Conference

Invited Lectures

S. No.	Details of the programme	Date	Scientist/ Research staff
1	"Solar Energy Application: opportunity and challenges" in Institute of Technology, PP Savani University, Near Bharuch	March 7, 2020	Er. Asim Kumar Joshi
2	Workshop on "Gujarat CAN 2020 — Climate action now" Delivered the keynote lecture on "Solid waste management and climate change linkages" at IIT Gandhinagar	February 13, 2020	Dr. Gaurav Mishra
3	National Seminar on "Science and technology for rural development" Delivered the keynote address on "Renewable energy for rural sustainable development" at MS University, Vadodara	February 11, 2020	Dr. Gaurav Mishra
4	NAHEP-National Conference on "Agricultural engineering: 50 years of service of farmers through agro- entrepreneurship" and invitation as Guest of Honor for the inaugural function at Dr. PDKV, Akola Delivered a lecture on "Entrepre-neurship in agriculture sector and SPRERI introduction"	November 29, 2019	Dr. Gaurav Mishra
5	Delivered a lecture on "Futuristic renewable energy technologies" to the participants during Model training course on green energy initiatives in agriculture to combat climate change organized by Godhra Agricultural University at SPRERI, VV Nagar	October 21, 2019	Dr. Madhuri Narra

S. No.	Details of the programme	Date	Scientist/ Research staff
6	Model training course on green energy initiatives in Agriculture to combat climate change organized by college of Agricultural Engineering & Technology, AAU, Godhra • Prospects of organic waste utilization for a bio-refinery in India • Solar energy application: opportunity and challenges and designing of grid tied solar photovoltaic power plant • Prospects and challenges for liquid bio-energy towards sustainable development	October 18, 2019	Dr. Geeta Kumari Dr. Sachin Gupta Dr. Shaishav Sharma
7	Expert lecture on "Entrepreneurial opportunities and challenges in India" at Indore Institute of Management and Research, Indore	September 28, 2019	Dr. Gaurav Mishra
8	Delivered a lecture on "Waste management" during the short training programme on futuristic technologies in industries, BVM Engineering College, Vallabh Vidyanagar	July 16, 2019	Dr. Madhuri Narra
9	International Conference on "Entrepreneur-ship in agriculture and renewable energy sector" held at Dr. PDKV, Akola • Entrepreneurship opportunities in renewable energy: solar energy conversion technologies	March 15-16, 2019	Dr. Ramkishore Singh

National Conference

S. No.	Details of the programme	Date	Scientist/Research staff
1	National Seminar on "Waste to Wealth: opportunities & challenges", Government Engineering College, Bartonhill, Trivandrum • Solid waste management and possible strategies for technology selection	March 5-6, 2020	Dr. Gaurav Mishra
2	5th UGC National Conference on "Current trends in biological sciences - III (CTBS -2020)" *Poster presentation on* • Insights into the structural diversity, intermolecular interactions and molecular docking in fungal β-glucosidases	February 15, 2020	Dr. Darshan Rudakiya

3	National Conference on "Novel trends and advances in Pure and Applied Biological Sciences", NVPAS, VV Nagar *Oral presentation on* • Production and evaluation of biomass pellets as a firewood substitute *Poster presentation on* • Out-door cultivation of micro-algae in vertical column photobioreactor as well simultaneous bioremediation of raw dairy waste water and its post-harvesting methods **(Best Poster Award)** • Isolation, identification and production of cost-effective hydrolytic enzymes by a newly isolated cellulo-xylano fungal strain *Aspergillus tubingensis*	February 25-26, 2020	Mr. Alok Sivaprasad Vishwakarma Dr. Shaishav Sharma Ms. Nidhi Patel

Meeting / Workshops

S. No.	Details of the programme	Date	Scientist/Research staff
1	2nd International Conference on Rural technology development and delivery organized by Rural Technology Action Group (RuTAG), IIT, Chennai "Displayed SPRERI renewable energy technologies"	March 12-14, 2020	Dr. Madhuri Narra Er. George Samson
2	Participated in one day seminar on "Organic waste for bio-gas, compost, fertilizer and power" organized by Innovative Through Forum, Ahmedabad	March 7, 2020	Dr. Madhuri Narra Er. Samir Vahora
3	Participated in poster and oral presentation at Department of Chemical Engineering, Indian Institute of Science Education and Research, Bhopal • Production of activated carbon from groundnut shell via chemical activation • Production of pellets from groundnut shell • Oxidative fast pyrolysis of sawdust using fluidized bed reactor	February 28-29, 2020	Dr. Geeta Kumari Er. Bhavin Soni Er. Mayank Parmar
4	2nd Annual sustainability fair 2020, IIT Gandhinagar, Gandhinagar	February 28, 2020	Er. George Samson Er. Shradhdha Pandya
5	23rd Workshop of All India Coordinated Research Project on "Energy in agriculture and agro-based industries", MPUAT, Udaipur • Presented progress reports for 19-20 and proposed programme for 20-22 in respect of solar energy, bio-conversion, thermo-chemical conversion, liquid bio-fuels, demonstration of RE systems and energy management in agriculture activities	February 17-20, 2020	Dr. Gaurav Mishra Dr. Madhuri Narra Dr. Ramkishore Singh Dr. Sanjeeb Kumar Karmee Er. Samir Vahora Er. Asim Kumar Joshi Dr. Geeta Kumari

S. No.	Details of the programme	Date	Scientist/Research staff
6	Expert committee meeting of technology interventions for addressing societal needs at Administrative Staff College of India, New Delhi	February 5-6, 2020	Dr. Gaurav Mishra
7	Annual review workshop of consortium research project on "Energy from agriculture" • Presentation of annual progress report and new project proposals	January 27-30, 2020	Dr. Gaurav Mishra Dr. Madhuri Narra Dr. Sanjeeb Kumar Karmee
8	Workshop on "Capacity augmentation for the CSG SEED Division, DST, IIT Bombay, Mumbai	January 20-22, 2020	Mr. Manoranjan Kumar Shukla Er. Samir Vahora Er. George Samson
9	53rd Meeting of Academic Council of Anand Agricultural University, Anand at AAU, Anand	January 13, 2020	Dr. Gaurav Mishra
10	Presented 1st annual progress report of the project entitled "Next generation bio-lignin nanoparticle synthesis from lignocellulosic agro-residual waste materials using natural deep eutectic solvents", GSBTM, Gandhinagar	January 3, 2020	Dr. Shaishav Sharma
11	District level workshop for Women Empowerment organised by SARATHI (Mahisagar), NGO, Lunawada, Mahisagar	December 20, 2019	Mr. Manoranjan Kumar Shukla
12	Trained and demonstrated the operational procedure of solar bio-gas refrigeration plant to the team ongoing STTP organized by BVM engineering college, Vallabh Vidhynagar, Anand	December 11, 2019	Er. Asim Kumar Joshi
13	Attended a meeting to discuss about plastic pyrolysis and waste management with Mr. Sampath Subramaniam, MD of Pyrogreen, National solid waste association of India and Rami Hakala, BMH Technology, Finland at SPRERI	December 5, 2019	Dr. Gaurav Mishra Dr. Madhuri Narra Dr. Sanjeeb Kumar Karmee
14	IRMA – Management Development, Topic: Qualitative and quantitative research methods, IRMA, Anand	November 14-16, 2019	Mr. Manoranjan Kumar Shukla
15	Attended expert committee meeting for DST-SEED TSP Scheme and presented STI-HUB project proposal at Administrative Staff College of India, New Delhi	October 24, 2019	Dr. Gaurav Mishra Dr. Ramkishore Singh
16	Attended Waste to Value CII-DST India-Netherlands: Technology summit at New Delhi	October 15, 2019	Dr. Madhuri Narra
17	Expert committee meeting on "Scheme for young scientists and technologists", IIT Delhi	October 14-16, 2019	Dr. Gaurav Mishra

S. No.	Details of the programme	Date	Scientist/Research staff
18	Presentation on a project proposal entitled "Implementation of a self-sustainable model for energy generation by adopting a patented clean technology for conversion of 3.5 TPD mixed organic waste into methane and bio-fertilizer", DBT, New Delhi	September 4, 2019	Dr. Madhuri Narra Dr. Gaurav Mishra
19	Attended a meeting for Panel of interview for the post of project assistant as Subject Expert at G H Patel College of Engineering & Technology, Vallabh Vidyanagar	September 3, 2019	Dr. Gaurav Mishra
20	Panel meeting to revise of IS-13152 (Part 1): 2013 'Portable solid bio-mass cook stove (Chulha) - specification' at Manak Bhavan, New Delhi	August 29, 2019	Dr. Gaurav Mishra
21	Attended 'Outreach session on various problem areas and their solutions via biotechnology interventions' organized by GSBTM, Gandhinagr	August 5, 2019	Dr. Shaishav Sharma
22	Attended the meeting to review progress and onsite inspection of activities of Rural hybrid energy enterprise system supported under Indo UK collaborative research programme for bridging the rural urban divide (INDO-UK BURD) programme organized at Department of Energy, Tezpur University, Nappam, Tezpur	August 3-4, 2019	Dr. Gaurav Mishra
23	Attended Scheme for young scientist and technologists screening meeting to screen the proposal received under "Call for Proposals', DST at Administrative Staff College of India, New Delhi	July 11-12, 2019	Dr. Gaurav Mishra
24	Attended the Brainstorming session for BIOTHON-Hackathon of biotech solutions for state problems at GSBTM, Gandhinagar	June 28, 2019	Dr. Madhuri Narra
25	Expert committee meeting on "Technological intervention for addressing societal needs" at HRDC, JNU, New Delhi	June 12-13, 2019	Dr. Gaurav Mishra
26	Attended Corporate social responsibility Summit held at Jaipur organized by NGO Box	June 4, 2019	Dr. Sanjeeb Kumar Karmee Dr. Shaishav Sharma

Visitors to the Organization

- Prof. Vijay S. Moholkar, Professor of Chemical Engineering and Head, Centre for Energy, Indian Institute of Technology, Guwahati, Assam visited SPRERI on February 28, 2020.
- Dr. Sangita Kasture, Director, DBT, Ministry of Science and Technology visited SPRERI on February 15, 2020, New Delhi.
- Mr. Jayanti Mori, Chief Programme Executive and Mr. Sandip Yadav, Senior Programme Manager from BAIF, Vadodara visited SPRERI on December 27, 2019.
- Mr. Vikas Vaze, Chief Executive Officer and Mr. Nitin M. Vyas, Vivekanand Institute of Vocational & Entrepreneuril Competence, Shroffs Foundation Trust, Vadodara visited SPRERI on December 10, 2019.
- Mr. Sampath Subramaniam, Chairman-Southern Chapter, National Solid Waste Association of India, Hyderabad along with Mr. Rami Hakala, Senior Sales Manager, BMH Technology, Rauma, Finland visited SPRERI on December 05, 2019.
- Mr. S.B. Dangayach, Ex-MD, Sintex Limited and Founder Trustee, Innovative Though Forum, Ahmedabad visited SPRERI on November 26, 2019.
- Mr. Rohit Nagargoje, Industry partner representative, R&D Director, MASH Energy India Pvt. Ltd visited SPRERI on 7 November, 2019.
- Dr. Ahmad Arabkoohsar, Associate Professor, Department of Energy Technology, Aalborg University, Denmark and Dr. Meisam Sadi, postdoc Research Associate, Department of Energy Technology, Aalborg University, Denmark visited SPRERI during November 6-10, 2019.
- Dr. Shivani Mishra, Director, Department of Social Work, Sardar Patel University, Vallabh Vidyanagar visited SPRERI on June 25, 2019.
- Mr. V. K. Srivastava from Technocraft, Ahmedabad visited SPRERI on April 26, 2019.
- Dr. Anil Kumar Dubey, Principal Scientist & LCPC, CRP on Energy from Agriculture, ICAR-CIAE Bhopal visited SPRERI during April 25-26, 2019.
- Mr. Yaswanth Tippireddy, Manager (Operations), Godrej Agrovet, Andhra Pradesh visited SPRERI during April 15-16, 2019.

Team

Director
- Dr. Gaurav Mishra

Solar Energy Division
- Dr. Ramkishore Singh
- Dr. Sachin Gupta
- Er. Falgun Keyoor Raval
- Mr. Mahendra Padhiyar
- Mr. Mukesh Jadav
- Er. Asim Kumar Joshi
- Dr. Arunendrakumar Tiwari
- Er. Milan Sojitra
- Mr. Prakash Machhi

Bioconversion Technology Division
- Dr. Madhuri Narra
- Dr. Kiran Kumar Adepu
- Dr. Shaishav Sharma
- Er. Gaurav Dixit
- Ms. Nivedita Iyer
- Mr. Priyank Kachhia
- Ms. Arjoo Deshpande
- Mr. Samir Dedania
- Ms. Jinal Upadhyay
- Mrs. Aesha Patel
- Mr. Ashok Harijan
- Mrs. Manjula Vadhel
- Er. Balasubramanian Velmurugan
- Dr. Shyamali Sarma
- Dr. Darshan Rudakiya
- Ms. Deepti Davla
- Mrs. Kumud Macwan
- Er. Vinod Rathod
- Mr. Alok Sivaprasad Vishwakarma
- Mrs. Ekta Shah
- Ms. Manisha Harijan
- Ms. Nidhi Patel
- Mr. Harman Parmar
- Mr. Ashok Mochi

Thermo-chemical Conversion Technology Division
- Dr. Sanjeeb Kumar Karmee
- Dr. Sreedhar Gundekari
- Er. Urvish Patel
- Er. Ganesh Pawar
- Dr. Geeta Kumari
- Er. Ashwin Tirpude
- Er. Bhavin Soni
- Mr. Ashok Patel

Technology Transfer & Extension Division
- Mr. Manoranjan Kumar Shukla
- Mr. George Michael Samson
- Er. Shradhdha Pandya
- Mr. Shailesh Solanki
- Er. Samir Vahora
- Mr. Paresh Mer
- Mr. Minesh Suthar

Administration
- Mr. Keyur Prajapati
- Mr. Hiteshkumar Dalwadi
- Mrs. Aida Mascarenhas
- Mr. Bhupendra Prajapati
- Mr. Ramesh Bhoi
- Mr. Bhupat Parmar
- Ms. Pragna Dave
- Mr. Harshad Suthar
- Mr. Hasmukh Vaghela
- Mr. Dahya Harijan
- Mr. Rajesh Machhi
- Mr. Ishwar Harijan

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE - VALLABH VIDYANAGAR
BALANCE SHEET AS ON - 31 - 03 - 2020

FUNDS & LIABILITIES	2019	2020
CAPITAL FUND		
As per last year	1082669.20	1082669.20
PROJECT FUND		
Balance from last year	11449117.63	3222660.63
Add / Less during the year	8226457.00	16052705.95
(Annexure - A) *	3222660.63	19275366.58
EAR MARKED FUND		
1. Building Fund Provision		
Add : During the year		
	3364376.00	3364376.00
2. Depreciation Investment Fund	455244.00	455244.00
3. R & D Fund (As per last year)	7272538.73	8103647.83
Add : During the year	831109.10	0.00
Less : During the year	8103647.83	8103647.83
DONATION		
Balance from last year	1234001.00	1234001.00
Add : During the year	0.00	586100.00
	1234001.00	1820101.00
PROJECT EQUIPMENT		
Depreciated value of Equip.from last year	98370566.35	106144951.35
Add : During the year	7774385.00	1825562.25
Less : Depreciation Annexure - C	106144951.35	107970513.60
DEPRECIATION FUND		
As per Block - Annexure - B	5947504.30	6125628.30
LIABILITIES		
1. Contigent Development Fund	133400.00	133400.00
2. Graduity Fund	7297380.39	7506526.08
3. Endowment Fund -	1413979.75	1313274.75
Add : During the year	70700.00	45965.00
Less :	171405.00	0.00
Annnexure - D	1313274.75	1359239.75
4. Staff Welfare Fund	246296.50	392334.50
5. Share & Care Fund	152835.00	152835.00
6. Quiz Programme Fund	58262.00	58262.00
7. Maintenance Fund (Core Grant)	547179.00	725879.00
Extension activity fund	236938.00	0.00
Income & Expenditure A/C		
SURPLUS / LOSS		
From Last/current Yr Balance Sheet	630174.93	489906.74
Add - During the year		
TOTAL		
Less - During the year	140268.19	634515.79
TOTAL	489906.74	-144609.05
TOTAL	**33885575.34**	**50410900.19**

ASSETS	2019	2020
FIXED ASSETS		
1. Furniture & Fixtures	249808.62	249808.62
2. Electric Fittings	162350.85	162350.85
Add : During the year	0.00	0.00
	162350.85	162350.85
3. Mobile Phone	19600.00	19600.00
4. Institute Equip.(R & D / Others)	1071372.00	1071372.00
5. Car - GJ-23 AF-0282	585597.00	585597.00
6. New Jeep - GJ-23-GA-0488	834000.00	834000.00
	2922728.47	2922728.47
INVESTMENT		
1. Fixed Deposit	11217166.00	11946607.00
2. Deposit in LIC - Graduity Scheme	7297380.39	7506526.08
	18514546.39	19453133.08
LOANS & ADVANCES		
1. Tax Deduction at Source	1050501.06	1423275.06
2. Telephone Deposit	20313.00	20313.00
3. CGM Deposit (Oil Diesel & Petrol)	12400.00	12400.00
4. Indian Oxyzen Ltd., Deposit	4252.94	4252.94
5. Mobile Phone Deposit	4680.00	4680.00
6. Broad Band Security Deposit	3000.00	3000.00
7. Gas Cylinder Deposit	10350.00	10350.00
8. Security Deposit (GEB - New DP)	100920.00	100920.00
9. Loan to Staff & Advance to Project	729642.00	729642.00
10.Intrest Accrued	459923.16	498586.96
11. Gujcost to be recover	24800.00	0.00
	2420782.16	2807419.96
BALANCE :		
Bank Balance	9906999.32	25125352.68
Cash Balance	120519.00	102266.00
	10027518.32	25227618.68
TOTAL	**33885575.34**	**50410900.19**

Accounts Officer
Sardar Patel Renewable Energy Research Institute
Accounts Officer

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

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

Chartered Accountants

Director
Sardar Patel Renewable Energy Research Institute
Director

Date :- 10.07.2020
Place :- Vallabh Vidyanagar

Abbreviations

%	Percentage
AAU	Anand Agricultural University
AHR	Anaerobic Hybrid Reactor
BVM	Birla Vishvakarma Mahavidyalaya
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CRP	Consortia Research Platform
CV	Calorific Value
d	Days
DLM	District Livelihood Manager
DMSO	Dimethyl Sulfoxide
DST	Department of Science and Technology
EAAI	Energy in Agriculture and Agro-Industries
EDAX	Energy Dispersive X-Ray Analysis
FEG	Field Emission Gun
GEDA	Gujarat Energy Development Agency
GoI	Government of India
GUJCOST	Gujarat Council of Science and Technology
H_2	Hydrogen
H_3PO_4	Phosphoric Acid
HRT	Hydraulic Retention Time
ICAR	Indian Council of Agricultural Research
IPA	Isopropyl Alcohol
ISRRE	CL Patel Institute of Studies & Research in Renewable Energy
kL	Kilo Liter
KOH	Potassium Hydroxide
$L\ kg^{-1}$	Liter per Kilogram
LPD	Liters per Day
$Mg\ L^{-1}$	Milligram per Liter
MS	The Maharaja Sayajirao University of Baroda
N_2	Nitrogen
NADES	Natural Deep Eutectic Solvents
NAU	Navsari Agricultural University
NRLM	National Rural Livelihood Mission
O_2	Oxygen
PM	Particulate Matter
ppm	Parts per Million
PVA	Polyvinyl Alcohol
RE	Renewable Energy
SEM	Scanning Electron Microscopy
SPRERI	Sardar Patel Renewable Energy Research Institute
SPU	Sardar Patel University
THF	Tetrahydrofuran
TS	Total Solids
TSC	Total Solids Concentration
$ZnCl_2$	Zinc Chloride

List of Technologies for Commercialization

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

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