



SPRERI
Striving for Excellence

ANNUAL REPORT

2022-23



SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE

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Highlights of the Year

SPRERI is one of the pioneer institutes carrying out research in renewable energy technologies, to provide sustainable energy solutions for day-to-day life. To tackle the economic and social impact of climate change on the environment the researchers are focused on ensuring renewable energy based research in a sustainable manner that leads to reduced environmental impact and reduced carbon emissions. Technologies for the utilization of agro waste and kitchen waste have been developed and commercialized and are successfully being used by the beneficiaries.

India has set its sights on becoming energy-independent by 2047 and achieving Net Zero by 2070. To achieve this target, increasing the use of renewable energy use across all economic spheres is central to India's Energy Transition. Team SPRERI has taken up initiatives on green hydrogen and at the institute and is working on projects for generating renewable energy based solutions.

The Thermo-chemical Conversion division has been contributing in the area of biomass gasification, and torrefaction for thermal application. In addition, the division has developed technology for wastewater treatment for bulk milk chillers, which has a capacity of testing 50 L/h. Under the proposed solution, the team executed biomass and char-based sorption studies. The system is ready for field demonstration.

The Bio-chemical conversion team has worked on Bio-methanol: The next-generation biofuel from biogas by methanotrophs. Mitigation of methane to useful products like methanol will lead to energy generation and reduce the toxic effects of methane. The division was successful in delivering a prototype for methane to methanol conversion using the biological route.

The Solar energy division is developing thermal energy storage for solar-driven cold storage. A cold room of 45m³ volume has been installed on the SPRERI campus. The new cold room was tested under no load conditions on both grid and solar supply, and the system is found performing better. Further research and development is in progress.

The Technology transfer and Extension division continues to create awareness among the rural community for the technologies developed at SPRERI. More than 45 demonstration programmes which were conducted and attended by 3,500 people from across Gujarat. In addition, the division is executing a few CSR projects with a focus on rural development by introducing renewable energy based technology.

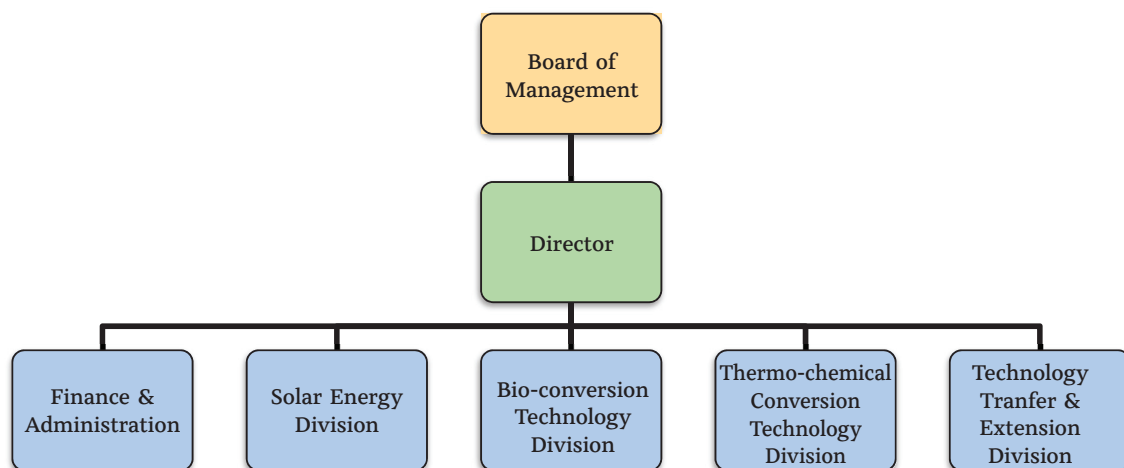
SPRERI has been supporting student internships by providing them hands-on experience they require for successful careers. Twenty students gained experience on renewable energy based pilot scale interventions.

SPRERI, also organised its flagship event open house for two days on 24th and 25th of January 2023 with the objective of showcasing the technologies developed at SPRERI. A footfall of 2,600 people was noted where students and staff from various schools and colleges, professionals, entrepreneurs, farmers and others interested in renewable energy visited the institute.



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 recognised 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 project funds to make it self-supporting. As a renowned renewable energy (RE) research institution, it is recognized for postgraduate 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 are pursued through field evaluation and demonstrations, training and entrepreneurship development, awareness programmes and integrated development of selected tribal villages.



Vision & Mission

VISION

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

MISSION

To achieve excellence in research, development, and commercial deployment of renewable energy technologies including education and training for the promotion of environmentally sustainable technologies with public-private cooperation for India and developing global economies.



Board of Management

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1.1 Solar Cooking

Design and performance optimization of thermal storage device for integration with Fresnel lens concentrator with a tracker for cooking application

Tracker development:



Fig. 1: Fresnel lens integrated with dual-axis tracker and thermal storage device

The Fresnel lens is successfully adapted to the tracker and successfully tested for proper sun tracking and its focus (Fig 1). The Fresnel lens has a 450 concentration ratio and its focal point can reach temperature $> 550^{\circ}\text{C}$. A stagnation temperature test of the Fresnel concentrator was carried out for 3 days. For $\text{DNI } 200 - 400 \text{ W/m}^2$; the temperature at the focal point was observed in range the $255 - 583^{\circ}\text{C}$. The focal point temperature was observed above 350°C for 7 to 7.5 h/day i.e. during 9:30 am to 4:00 pm.

Thermal storage device development

A cylindrical thermal storage device with concentric rings inside was developed. It was tested for charging using an electrical heater and discharging through tested for water boiling and cooking rice and lentils. During

the water boil test, a total of 3 batches were boiled up to 95°C and the 4th batch was heated up to 82.9°C . The efficiency of the device was found 41.3 %. A cooking test was carried out for boiling rice and lentils. During the cooking test, a total of 3 batches of both were cooked. The test results are shown in Table 1. The integration of the developed thermal storage device with Fresnel system was successfully done and its charging and discharging test is in progress.

Table 1: Test results for cooking using TSD

Batch No.	Item name and quantity (dry wt., g)	Water quantity, g	Cooking time recorded, min
R1	250	500	24
L1	200		32
R2	250		38
L2	200		47
R3	250		43
L3	200		66
R1, R2 & R3 stand for batches of rice. L1, L2, & L3 stands for batches of lentils.			

Solar evacuated tube heat pipe collector with three pressure cookers in series

The system was modified and three 5 L capacity jacketed pressure cookers were connected with the solar ETC heat pipe collector system, shown in Fig 2. The system was tested for cooking rice, lentil and curry potato-tomato. During the entire day of testing 9:00 am to 5:00 pm, the system was able to cook, on a dry weight basis, 3.2 kg rice, 2.0 kg lentils, and 1.6 kg curry. Compared to an earlier reported system with one pressure cooker, this system was able to cook ~50 % more food on a dry weight basis. Additional benefit of the system was that the user can cook 3 items simultaneously, whereas in

single cooker system, food can be cooked one by one. The tentative cost of the prototype is ~₹ 66,000/- and the simple payback estimated is ~ 2.8 years, compared to ~ 4 years for the single the cooker system.



Fig.2: Solar ETC-HP collector with three pressure cooker in series

1.2 Solar Drying

Thermal energy storage-based indirect solar dryer

The system was upgraded with provisions for dryer exhaust air recirculation through adaption of Pneumatic actuator-driven air dampers and a high-temperature humidity sensor-based controller. The system was tested successfully with an artificial load of wet clothes and the recirculation automation system was further upgraded for proper and quick response. The testing of the system with load in recirculation mode is in progress.

1.3 Solar Desalination

Solar compound parabolic concentrator for desalination of groundwater

The compound parabolic concentrator with evacuated tubes and heat pipe (CPC-ET-HP) based solar still was further modified to improve the performance. The condenser cover material was changed, instead of polycarbonate sheet (low thermal conductivity 0.22 to $0.24 \text{ Wm}^{-2}\text{K}^{-1}$) glass (thermal conductivity 0.9 to $1.2 \text{ Wm}^{-2}\text{K}^{-1}$)

was used with base area increased by 75 %. The other components used were the same. The system is shown in Fig. 3.

The performance of the developed CPC-ET-HP still was carried out for a 15 L load with the pump operational for 15 min and off for 15 minutes during (09:00 am to 05:00 pm). The maximum distilled water production observed was ~10 L for 24 h cycle i.e. 1.93 L/m^2 of gross area. However, compared to a simple FRP-based solar still, the performance is observed to be 123% more in terms of distillate production L/m^2 . Further modifications on improvement in the system design to improve its performance are in progress

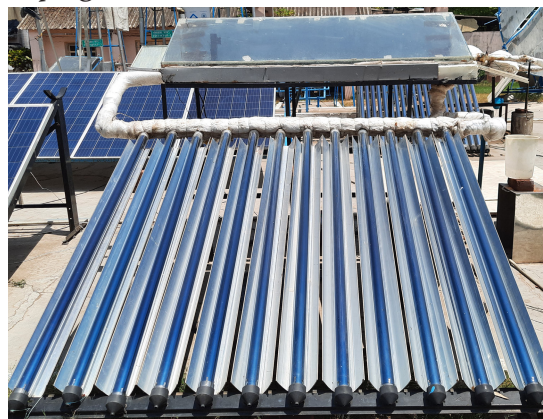


Fig. 3: CPC-ET-HP still heat pipe solar still (Prototype-3)

1.4 Solar Refrigeration

Thermal energy storage for solar-driven cold storage

During experiments with the existing setup, comprising an already available bunkhouse with door and window converted into cold room, it was observed that there is air leakage and a lot of heat gain for near zero temperature storage due to 50mm insulation thickness. So, a new cold room of size 5m X 3m with 100mm insulation was installed on the SPRERI campus (Fig. 4). To avoid heat gain, it was provided with a shed. To provide

minimum 500 VDC for system operation, solar PV arrays (02) connected in parallel were installed on the ground.



Fig.4: Installed new cold room and PV panels on the ground

Also, considering the ASHRAE standards, i.e. 80-95% RH to be maintained in a cold room during storage, a fully automated ultrasonic humidifier was installed in the cold storage. The relative humidity profile observed before and after humidifier is shown in Fig 5.

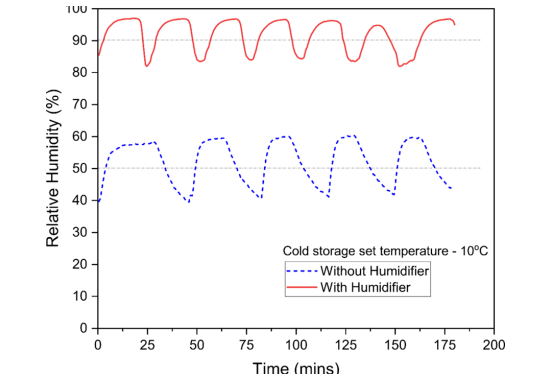


Fig. 5: RH profile inside cold room before and after humidifier installation

The new cold room was tested under no load conditions on both grid and solar supply. Preliminary tests are done for 10°C set point temperature of the room, as per ASHARE guidelines. Since there is a temperature augmentation due to continuous recirculation of air, the cold room temperature at the centre of the cold room was observed in range 7 to 17.5°C. Under no-load conditions, compared to test runs of winter, the compressor running time was observed to increase by 6 minutes and consequently, the compressor OFF time

was reduced by 8.5 minutes as shown in Fig. 6. Thermal storage panel integration, automation and control work is in progress

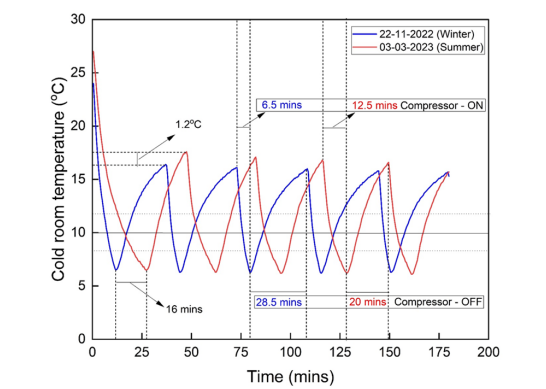


Fig. 6: Cold room temperature during no load test for winter and summer

Design refinement of SPRERITECH solar refrigerator with ice bank for medicine & vaccine storage in remote areas

- The upgraded version of the solar refrigerator was found working satisfactorily for both the winter and summer seasons for more than 20 and 10 continuous days. The temperature profiles of both the tests are shown in Fig. 7 and 8. The temperature of load and chamber both were found maintained within 2-8 °C meeting the requirements of WHO standards.

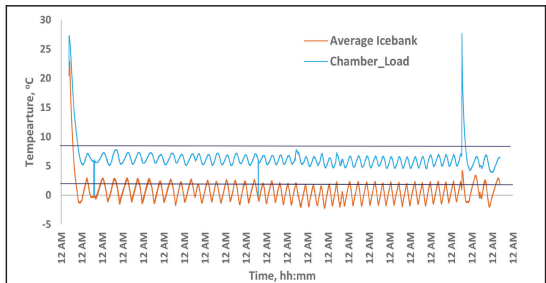


Fig. 7: Temperature profile for load test for winter season

- The system is being tested for different loads like banana, water etc. for finalizing the system specification and commercialization

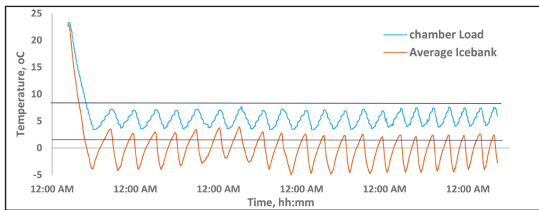


Fig. 8: Temperature profile for load test for summer season

1.5 Nano-materials in Solar Applications

Soot particles based nanofluid for use in solar thermal systems

Looking towards the promising results of these nanofluid in solar thermal collectors. It was planned to test the prepared nanofluid in a commercial-size flat plate collector in both direct absorption mode and conventional way of indirect heat transfer mode. A 2 direct absorption mode collector was developed in-house (Fig 9). For testing at a commercial

scale, around 70 L of nanofluid was prepared. Testing and performance evaluation is in progress. Further research to prepare nanofluid with other base fluids like synthetic heat transfer oil is in progress.



Fig. 9 Direct absorption type solar FPC collector on test bench

2.1 Production and Optimization of Polyhydroxybutyrate (PHB) from Lignocellulosic Sugar Hydrolysate

Polyhydroxybutyrate (PHB) has physical properties that closely resemble common synthetic polymers like polyethylene and polypropylene. Bioplastic production from these biopolymers is an eco-friendly strategy, which would reduce the dependence on petro-based plastic to some extent. PHBs are biodegradable intracellular polyesters that are assimilated by a number of bacterial species for energy and carbon storage. The relatively high cost of PHB compared to conventional plastic resins such as polyethylene and polypropylene has limited its use. Up to 30% of total production cost is attributed to feedstock cost; therefore, the search for low-cost feedstock is necessary. This project therefore aims to use cheaper substrates such as lignocellulosic biomass (wheat straw, sugarcane bagasse) derived sugars as carbon sources for microbial production of biopolymers. In this study, PHB-producing bacteria are isolated from various samples from different regions of

Anand, Gujarat. 40 strains have been isolated based on their preliminary screening and biochemical characterization followed by molecular identification. Isolates such as B2, B3, C1, D1, CW2, and MW2, were taken into consideration for PHB extraction based on their identification and screening results. During extraction, six procedures were performed for the optimization of the appropriate protocol. B2 and CW2 gave the best results among other strains. Sugarcane bagasse (SB) and wheat straw (WS) were selected for pre-treatment studies. SB resulted in a higher yield of reducing sugars as compared to WS. The yield of PHB was found to be 51% DCW from glucose and 31% DCW from SB hydrolysate. Soil biodegradation capacity of PHB was observed to be 14%.

2.2 Development of a Microbial Consortia for Composting of Rice Straw

This work aims to develop a microbial consortium for efficient composting of rice straw which is a major agricultural by-product. The current practice of stubble burning has posed a major threat to the environment and an immediate alternative practice of rice

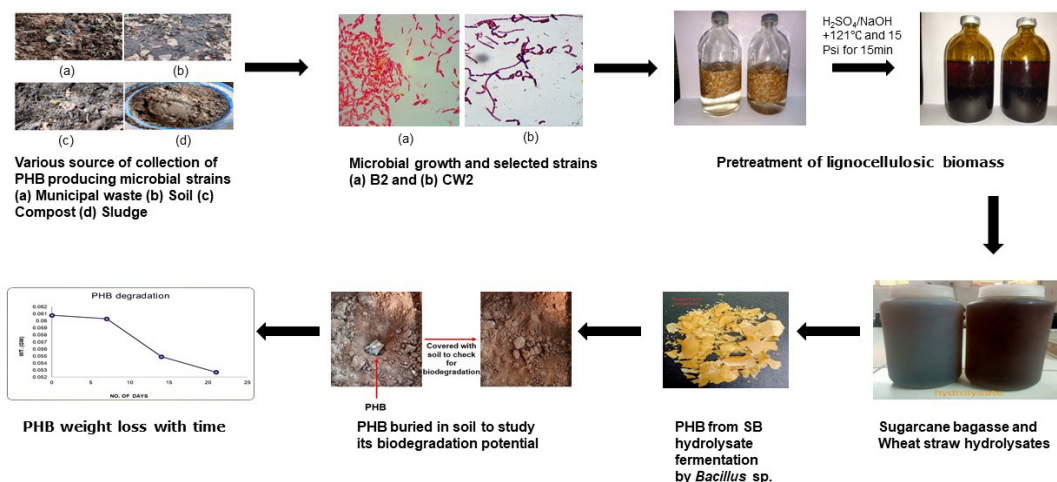


Fig.10: PHB production

straw disposal is the need of the hour. Rice straw is a major by-product obtained from rice cultivation, which is composed largely of lignocellulosic materials amenable to general biodegradation. The disposal of rice straw is a problem due to the huge bulk material and slow degradation rate. In many countries, including India, a huge amount of straw is disposed of through open burning, which causes serious environmental problems as well as threats to public health. Hence, composting rice straw could be a solution since rice straw is a potential food source for microorganisms like bacteria, fungi and actinobacteria. Focusing on this issue, the current study developed a defined microbial consortia of fungal and bacterial strains that had the ability to decompose rice straw much faster than the natural process of decomposition. The microbial consortium developed in this study has high lignocellulosic activity and its application has enhanced the rate of biodegradation of rice straw composting process under ambient conditions. In contrast to the traditional composting method which takes 45–60 days, this study was successful in reducing the composting process to 25 days as indicated by various parameters such as C/N ratio, temperature, pH, TS, VS and

moisture content. To get a detailed insight into the composting process, the microbial diversity at various stages of composting was studied which revealed the dominance of Proteobacteria in the mesophilic phase with an increase in abundance of Bacteroidates and Firmicutes in the late thermophilic phase.

2.3 Bio-methanol: The Next-generation Biofuel from Biogas by Methanotrophs

Methane is a major toxic greenhouse gas generated from dumping grounds, landfills, oil and natural gas systems, agricultural activities, coal mining, stationary and mobile combustion, wastewater treatment, and certain industrial processes. Mitigation of methane to useful products like methanol will lead to energy generation and reduce the toxic effects of methane. Methanol can be used as a clean transportation fuel and its derivative di-methyl ether (DME) can be used as a replacement for LPG. Methanol also serves as the feedstock for the chemical, plastic and paint industries. This project aims to the isolation of potential methane-oxidizing microbes that can convert methane to methanol. Cowdung slurry (CS) was collected from a nearby cow shelter in Anand. Soil samples (SS) were collected from paddy fields of Bakrol

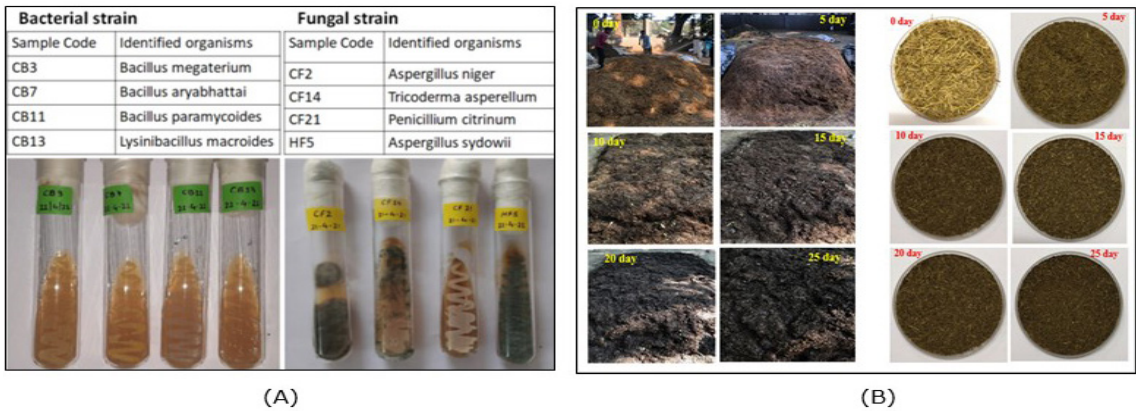


Fig.11: (A) Isolated and identified bacterial and fungal strains
(B) Wet compost and dry compost of rice straw collected at various time intervals

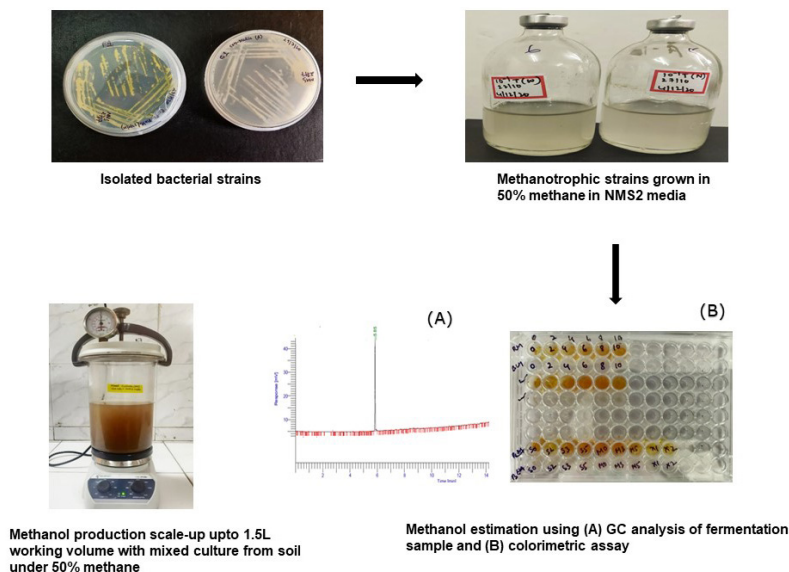


Fig.12: Biomethanol production from methane by methanotrophs

and Thasra areas of Gujarat. Isolation of methanotrophic bacteria was conducted using an enrichment technique in distilled water and modified nitrate mineral salts medium (NMS2). For identification and phylogenetic relationship of the potential isolates, 16S rDNA sequencing was carried out. Methanol produced by the mixed cultures was quantified by Gas chromatography analysis. Another confirmatory test available for the detection of very low concentrations of methanol in the fermentation broth is by using a simple colorimetric assay kit. The strains isolated and used were *Methylobacillusflagellatus*, *Plastorhodobacterdaqingensis*, *Halomonas-lactosivorans* and *Zobellelladenitrificans*. Initially, the experiments were carried out in small serum bottles of 100 mL and were then scaled to a 3L reactor (30x). The highest methanol-producing strain was *Methylobacillusflagellatus* which produced around 2.7 mM methanol after fermentation. This study was thus successful in delivering a prototype for methane to methanol conversion by biological route.

2.4 Agro Residues to Value-added Products for Industrial Applications

Due to the harmful impact of agro-waste on the environment, there is an urgent need to tap the potential and convert agro-residues into value-added products. Rice straw and banana stem is one such waste which has impacted the environment negatively to a large extent and needs to be addressed. Since, both these agro-residues have the potential to develop a wide range of value-added products, we intend to extract cellulose and convert it into MCC and CNC. Further, MCC/CNC would be used for the development of polymer films and bactericidal composites. Moreover, the banana stem would be used for the extraction of banana fiber and the development of HDPE/LDPE-based composites. The raw rice straw was used as the feedstock to obtain microcrystalline cellulose (MCC). Then the biomass was dried in an oven at 80°C for 8 hours and subjected to alkali treatment (NaOH concentration up to 4 %) in the autoclave on predetermined conditions. The biomass was then bleached with sodium chlorite (NaClO_2) in 2 % concentration. The

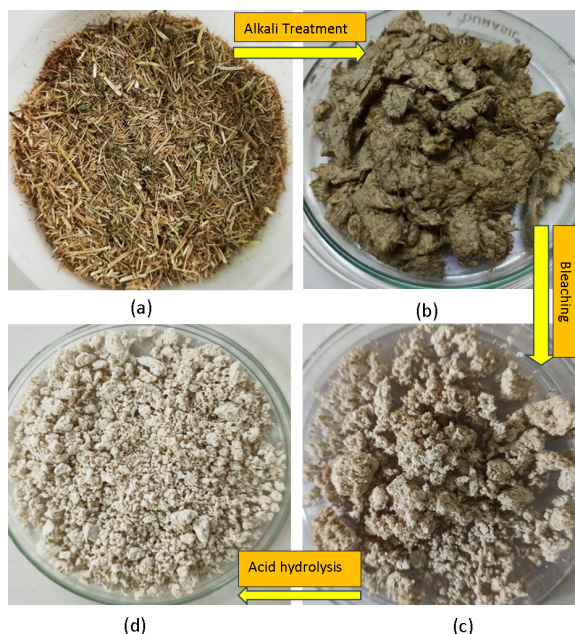


Fig.13: (a) Raw rice straw (b) Alkali-treated rice straw biomass
(c) dried rice straw biomass after bleaching (d) microcrystalline cellulose from rice straw

bleached biomass is then put for acid hydrolysis with hydrochloric acid in various proportions (up to 10 %) to obtain microcrystalline cellulose.

2.5 Development of Cellulose and Lignin based Nano Bio-composites from Agrowaste

Bio-nanocomposite is one of the remarkable achievements of nanotechnology in material science to replace conventional non-biodegradable petroleum based plastics for packaging applications. In general, bio nanocomposites are made up of biodegradable polymers (biopolymers) and bio based reinforcing material in the size range of 10–100 nm in one or more dimensions. Bio based materials could provide a solution for petroleum shortage and waste management problems. One of the potential reinforcing agents is agro industrial based cellulose and lignin. Such composites demonstrate improved properties as compared to the neat biopolymers due to the large surface area and high aspect ratio of nanoparticles. Pre-treatment of rice straw and cotton stalk using NADES solvents

was performed to obtain the cellulose and lignin fractions. Nanocellulose and lignin nanoparticles were synthesized using chemical (acid, base) treatments and particle size was observed to be in the range of 20 to 200 nm. Parameter optimization of acid concentration, bleaching time, hydrolysis time, sonication time etc. was performed using Design of Experiments (DOE) to construct factorial based orthogonal array (OA) of L₉ (3 levels, 4 factors) using Taguchi methodology. Bright field microscopy confirmed the images as rod shaped nanofibers.

2.6 Development of Advanced Biofuels and Bio-lubricants from High Lipid-producing Microalgae Strain

Biological wastewater treatment using microalgae represents a dual advantage of removing dissolved organic and inorganic pollutants along with the production of sustainable biomass feedstock for biofuel production. There are three main sources of wastewater intensively studied in alternative microalgal cultivation; municipal, industrial

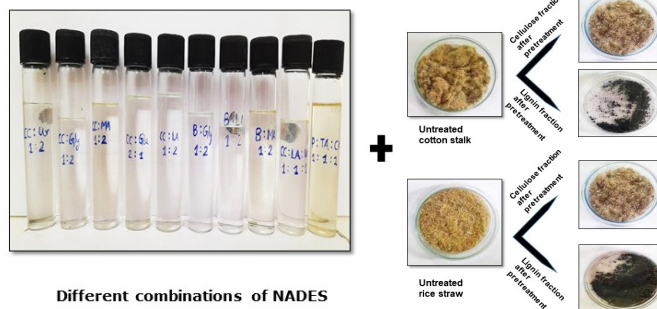


Fig.14: Different NADES combinations and cellulosic and lignin fractions after pre-treatment with NADES

and agricultural wastewater. Industrial effluents with low organic carbon can be treated by algae cultivation. Nutrients are recovered in the process for biomass and lipid formation and the treated wastewater can be re-used for algal cultivation or domestic purposes. The oil thus generated in the algal biomass from the valorization of effluents can be used as either biofuel or converted into more sustainable form of bio based lubricants with low toxicity and biodegradability. Bio-lubricants prepared from microalgae oils are reported to reduce the coefficient of friction upto 10 %. High MUFA and SFA content in the algal oils is

desirable for good lubricant properties like viscosity, lubricity, pour point and oxidative stability. Microalgae cultivation with in-house isolates has been initiated in tubular column photobioreactor (60L) and V pond (3000L). Oil extraction and biodiesel conversion of initial cultures grown on dairy wastewater was performed. Initial COD of dairy wastewater was around 2000 mg/L. Approximately, 1000L of dairy wastewater was procured from Amul Dairy and diluted to 3000L using tap water. The initial cycles were run for adaptation of the algal culture to dairy wastewater with minimal growth of 0.1 g/L DCW.



Fig.15: Microalgal strain growth and cultivation in dairy wastewater

3.1 Gasification

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

The team has updated the configuration of the SPRERI-Tech fluidized-bed gasification (FBG) system to prevent heat loss from the sand bed section and reduce system preparation time (Fig.16). The updated system was fabricated and tested in-house for longer duration trials (~48 h) to check its performance.



Fig.16: Fluidized bed gasification system installed at Swastik poha

Based on the energy audit conducted for thermal utilities (paddy roaster) at M/s. Swastik Traders, Umreth, Gujarat, a sawdust-based FBG system of 100 kg/h (i.e. 4,00,000 kcal/h) capacity was installed & matched with the thermal requirement of their paddy roaster. After the installation of the system, the first trial run was conducted for the paddy roasting application, and the FBG system showed stable operation. The paddy roasting temperature (i.e., $140 \pm 5^\circ\text{C}$) was maintained without any major fluctuation. During this

trial, the FBG system showed a sawdust consumption rate of 90 – 130 kg/h. Unlike open combustion of sawdust, no sparks/unburnt and smoke liberation were observed from the kiln of the paddy roaster.

The TCC team has identified a third beneficiary and the work subjected to the installation of the FBG system has been initiated.

Studies on air gasification of pyrolysis char from different agro-forestry residues

Over the last few decades, pyrolysis char has attracted global attention due to its high potential usage for a wide range of applications. However, its application as a fuel is still a less explored research area. With the carbon-dominated elemental structure, the bio-char obtained from the pyrolysis of various agro-forestry residues shows a calorific value in the range of 5019 – 7170 kcal/kg. It can be further used to generate fuel gases (producer gas). Along this line, the feasibility study of bio-char gasification was carried out to evaluate the energy potential of bio-char through air gasification. Sawdust and groundnut shells were selected as bio-char precursors. The bio-char of sawdust and GNS shows carbon content of 63.4 wt.% and 68.2 wt.%, respectively, and hydrogen content of about 3.5 wt.%. With dominant carbon and hydrogen structure, the bio-char of sawdust and GNS shows calorific value of 5750 and 5650 kcal/kg, respectively. However, due to pyrolysis, the net ash content of bio-char was increased, compared to the raw biomass. Further, the generated bio-char was gasified in SPRERI-Tech fluidized bed gasification system with air as a fluidizing media. In order to optimize the process, the gasification of both bio-char types was performed by varying the equivalence ratio

(ER). The effect of ER on process outputs (i.e. process temperature, gas composition, calorific values, FCE, and gas yield) was recorded for further evaluation of the process.

The energy cost was calculated by balancing all the cost-incurring parameters involved in the fuel conversion process (Table 2). As it is a feasibility study, manpower cost was excluded

Table 2: Cost of the energy conversion process

Sr. No.	Description	Sawdust char	GNS char
1.	ER	0.27	0.24
2.	Raw material cost	~ ₹ 20/kg	~ ₹ 20/kg
3.	Feed rate	33 kg/h	34 kg/h
4.	Electrical consumption	4 units/h	4 units/h
5.	Total input cost	₹ 690/h	₹ 710/h
6.	Total energy output	64,137 kcal/h (268 MJ/h)	80,488 kcal/h (337 MJ/h)
7.	Energy cost	93 kcal/₹ (₹ 2.6/MJ)	113 kcal/₹ (₹ 2.1/MJ)

3.2 Pyrolysis

The continuous pilot-scale intermediate pyrolysis system; In-situ utilization of pyro-gas

After successful feasibility trials of pyro-gas recirculation into the combustion chamber of SPRERI-Tech pilot-scale continuous pyrolysis system, pyrolysis experiments were carried out with different biomass to assess the effect of pyro-gas recirculation on the fuel requirement for the reactor heating. Based on the sets of experiments conducted for the selected feedstock (Sawdust, Groundnut shell and Cotton stalk) economic analysis was carried out for pilot-scale continuous pyrolysis system (feeding capacity: 12–15 kg/h).

The economics of pyro-gas recirculation was calculated considering average experimental values of average biomass processing rate, product yields, cost of biomass, electricity, and manpower. It was observed that with pyro-gas utilization for process heating, specific fuel consumption (SFC- kg LPG/

from the calculation. Here, the bio-char production cost (i.e., ₹ 20/kg) was considered based on 1 TPD char generating continuous pyrolysis system. With consideration of all the cost inclusive parameters, air-gasification of sawdust and GNS bio-char shows energy generation cost of 93 kcal/₹ and 113 kcal/₹, respectively.

kg feedstock) was reduced by 41.18%. In this regard, production cost was also reduced by a significant amount (~2.5 lakhs/annum; ~21%). Further, the unit energy cost (considering bio-char and organic phase of the bio-oil as a fuel) was also reduced by 22.15%.

3.3 Catalytic Pyrolysis of Biomass in Ex-situ Mode

Catalytic pyrolysis is preferred over non-catalytic due to the improvement in bio-oil quality since it promotes deoxygenation, dehydrogenation, cracking and aromatization. It basically cracks the heavy molecules into lesser viscous oil, thereby providing better stability and higher heating value.

To improve the quality of bio-oil, catalytic pyrolysis of biomass was performed in the SPRERI Tech batch-scale pyrolysis system in ex-situ mode. The schematic diagram of the reactor set-up is shown in Fig. 17. The experimental set-up consists of (a) carrier gas, (b) a main reactor, (c) secondary reactor consisting of the catalyst bed, (d) a condenser and (e) Bunsen burner. The main reactions occur in the main reactor, while

the product gases and liquid interact with the catalyst in the secondary reactor. The cotton stalk (CS) was used as feedstock and CaO and Fe₂O₃ as catalysts. The catalyst mass ratio was varied from 10–60 wt.% for each catalyst and the bio-oil and bio-char yield were evaluated. The bio-oil collected from the condenser–1 was kept in a beaker for two consecutive days for phase separation.

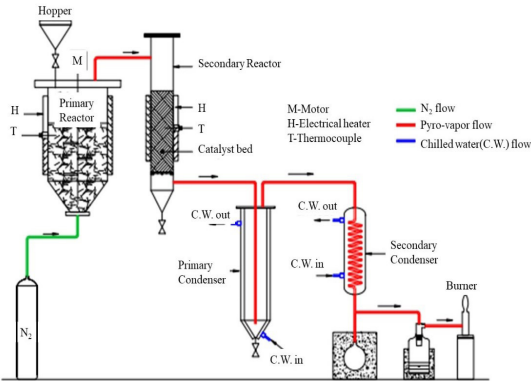


Fig. 17: Schematic diagram of SPRERI-Tech batch-scale pyrolysis system in exsitu mode (capacity: 1.0 kg/batch)

The basic properties of bio-oils such as viscosity, density, solid content, ash content, pH etc. were evaluated to detect their quality. Table 3 highlights the variation in the bio-oil properties obtained during non-catalytic and catalytic conditions. The highest organic fraction of bio-oil was obtained during 40 wt.% CaO loading. Due to the high content of the organic phase, the heating value is found to be 26.4 MJ/kg thereby indicating the deoxygenation power of CaO. The pH of the derived bio-oil is in the range of 4–5, thereby signifying less acidic in nature. The ash content is found to be low (0.1 to 0.8 wt.%) for all the cases, making it suitable for thermal applications. The bio-oils are viscous in nature (82–97 cP). Thus, slight upgradation of the bio-oil is needed prior to its direct usage in thermal applications.

Table 3: Summary of bio-oil properties during non-catalytic and catalytic pyrolysis of CS at 500°C in ex-situ mode

Bio-oil properties	Non-catalytic	Optimum catalyst loading	
		40 wt.% CaO loading	10 wt.% Fe ₂ O ₃ loading
Organic phase (wt.%)	6.6	15.8	8.3
Heating value (MJ/kg)	22.3	30.5	28.1
Density (kg/m ³)	1.03	1.04	1.10
Viscosity at 50°C (cP)	81.9	89.4	96.5
Solid content (wt. %)	2.1	3.2	5.3
Ash content (wt. %)	0.1	0.5	0.8
pH	4.6	5.1	5.0

Further, under the ex-situ mode of the catalytic pyrolysis process, the properties of bio-char are affected. It was observed that the calorific value of biomass increased significantly with ex-situ mode. In addition to this, the ex-situ catalytic pyrolysis process supports catalyst recovery and does not impart any adverse effects on bio-char yields and properties.

3.4 Value-added Products from Agro-residues

Feasibility study of agro-residues and their char-based water treatment unit

At every milk collection centre situated in the village, a refrigerated storage vessel (BMC-bulk milk chiller) is used to store the milk until its collection by the milk collection van is done. These vessels can accommodate 1000 litres of milk. After the dispatch of milk, it was washed with hot water and diluted flushing chemical, which generates ~50 litres of wastewater every day for a 1,000 lit capacity of BMC. In general, this waste stream is not treated and is dispensed to open ground or

municipal sewer lines. For the treatment of this water, the team has executed biomass and char-based sorption studies. Along this line, cotton stalk, groundnut shell and sawdust along with their respective bio-char were selected as bio-sorbents.

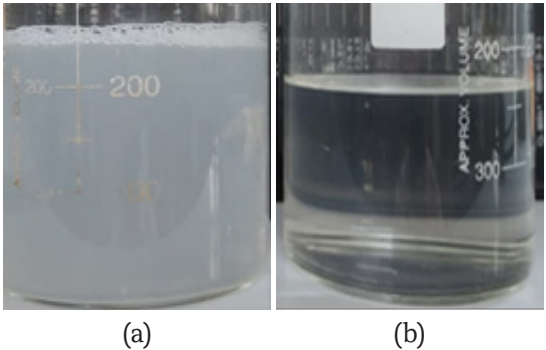


Fig.18: (a) raw BMC wastewater
(b) treated BMC wastewater

It was observed that BMC wastewater shows higher levels of BOD, COD, pH, and turbidity than the acceptable limits of Irrigation quality water; Type-E. In order to reduce and bring the level of these parameters under the prescribed range of irrigation water quality, the BMC wastewater was passed through the bed of sorption materials. Post-filtration, the levels of BOD, COD, pH and turbidity were measured. The obtained results suggest the feasibility of the selected feedstocks (except cotton stalk bio-char) to treat the BMC effluent

to use it as irrigation water (Fig.18). Further, the team is planning to demonstrate a pilot-scale BMC waste water filtration unit on-site. **Production, characterization and demonstration of char pellets as a fuel in the forced-draft cook stove**

In order to create an alternative use of rice straw (RS), pyrolysis was carried out in a SPRERI-Tech continuous pyrolysis system at 475 °C ± 15°C, wherein the process yielded 27 wt.% biochar, 33 wt.% of bio-oil, and ~ 40 wt.% (by balance) of pyro-gases. Further, the densification feasibility of RS biochar was evaluated with different waste/organic additive materials (i.e., tea waste, banana stem, potato peels, and starch).

The selection of the optimum contents of additives was determined by preparing char pellets by varying the additive contents (i.e., 5wt.%, 10wt.%, 15wt.%, and 20wt.%).It was observed that the durability and bulk density of char pellets have increased with the increase of additive contents (Table 4). However, ash contents and calorific value of pellets decreased gradually with an increase in additive contents. Reduction of ash content can be considered as a favourable change in pellet properties as higher ash content poses slagging and fouling

Table 4: Physio-chemical properties of RS char pellets with optimized contents

	VM	ASH	C	H	N	O	CV	Dura- bility	Bulk Density	Water Resistance
	wt.%	wt.%	wt.%	wt.%	wt.%	wt.%	kcal/kg	%	kg/m ³	%
RSC 100%	20.4	42.1	45.6	2.7	0.6	8.2	4,314	67	460	NA
RSC + TW 20%	42.3	32.9	42.0	4.1	1.0	19.9	4,247	97.2	580	67.6
RSC + BS 20%	39.8	34.3	42.9	3.5	0.6	18.7	3,910	97.3	560	72.0
RSC + PP 20%	37.6	33.6	45.1	3.9	1.1	16.3	4,185	98	594	68.5
RSC + ST 10%	37.1	38.1	47.8	4.6	0.4	9.1	4,787	98.5	595	72.3
*WDC	20.0	5.0	72.6	3.8	0.7	17.7	6,143	NA	378	83.9

RSC + BS 5% – Rice straw bio-char 95% + banana stems 5%
TW-tea waste, PP-potato peels, ST-starch, *WDC- wood charcoal chunks,
NA-not applicable

tendencies of combustion equipment and deteriorates the combustion performance of the fuel. With a gradual increase of additive proportions in char pellets, the certain mass fraction of bio-char (i.e., 5wt.% to 20wt.%) that holds higher ash content and calorific values, gets replaced with an equivalent mass fraction of additives. However, additives have comparatively less ash contents and calorific values than biochar. Due to this, the resultant ash content of char pellets reduces with an increase in the additive contents.

The performance of char pellets as fuel was assessed in compliance with BIS

standards in an improved biomass cook stove. The thermal efficiency test (Table 5) and emission measurement were carried out simultaneously. During the test, it was observed that RS pellets tend to form agglomerates, which led to ash fusion and the formation of clinkers during the glowing combustion phase. To avoid such scenarios, constant/periodic agitation of the combustion grate is required to disengage and remove ash particles. Due to this, RS char pellets are not suitable for static batch combustion applications (i.e., for domestic use in cook stoves).

Table 5: Thermal efficiency results of char pellets

Sr. No.	Types of char pellets	Calorific value	Burning rate	Thermal efficiency	Power output
		kcal/kg	kg/h	η %	P_o kW _{th}
1	RS Char + Tea Waste	4,247	2.9	31.8	4.6
2	RS Char + Banana Stems	3,910	2.7	31.5	3.9
3	RS Char + Potato Peels	4,185	3.1	28.6	4.2
4	RS Char + Starch	4,787	2.6	27.4	3.9
5	Wood derived charcoal	6,160	1.4	33.5	3.4

The emission measurement test (Table 6) was performed simultaneously with the thermal efficiency test. As per BIS, the net carbon monoxide emissions should be less than 5 g/MJd for an improved cook stove. The emission profile of all RS char pellet variants was found within the specified emission range of BIS.

Table 6: Emission profile of RS char pellets and wood charcoal

Sr. No.	Types of char pellets	O ₂	CO ₂	CO	Stack	CO
		vol.%	vol.%	ppm	°C	g/MJ _d
1.	RS Char + TW	17.4	1.6	285.0	39.0	3.2
2.	RS Char + BS	18.4	2.0	368.0	38.0	4.5
3.	RS Char + PP	19.5	1.8	317.0	38.0	4.0
4.	RS Char + ST	18.5	1.4	350.0	42.0	4.6
5.	Wood derived charcoal	10.7	0.8	501.4	58.0	4.1

The production cost of char pellets was calculated by considering three major cost-inclusive working capital, namely 1). Pre-processing cost of raw material, 2). Cost of the pyrolysis process, and 3). Cost of pelletization process, excluding the cost of manpower.

With the up-scaled char pellet production systems of 1 TPD and 10 TPD, the production cost would be ₹17/kg and ₹14/kg respectively.

Technology Transfer and Extension Division

4.1 Demonstrations

An effective, practical demonstration is the most needed method in extension work. Farm or field demonstration is a worthy way to show how a new technology works, and what effects it will have on the lives of the people attending the demonstration. SPRERI's Extension team keep conducting demonstrations on Renewable Energy Technologies developed at the Institute. More than 45 demonstration and dissemination programmes were conducted in seven districts of Gujarat in the year 2022–23. Other important places of the demonstration included Ambuja Cement Foundation (ACF), KodinarSarnal Morva Hadaf, and Sant Road.

and V.V. Nagar. This preliminary survey was for one of the huge projects commissioned in the area of biogas. A 3.5 TPD bio-methanation plant based on SPRERI's patented odourless technology was implemented at Karamsad. A model was prepared where the kitchen waste was collected, which was to be utilized for the plant. The team made great efforts, visiting more than 100 eateries around Anand and V.V. Nagar, to convince eatery owners to be a part of the project. The team worked to bring a change in people's mindset towards waste generation at source. Eighty-nine vendors including street hawkers, and small and big food junctions agreed to segregate dry and wet waste and give it to the plant.



Fig.19: Demonstration on IBCS

The extension team from SPRERI could connect to more than 3200 rural people through 45 demonstrations on Renewable Energy Technologies. Apart from RET demonstration, the team intensively worked towards data collection of food junctions around Anand

Fig. 20: Demonstration of segregation of kitchen waste

Educational trips make students think creatively and critically about what they see and experience. This helps students to develop their critical thinking skills and become more innovative learners. During the year 2022-

23, there were eight educational visits from different institutes. More than 400 students visited SPRERI from different places like Karamsad, V V Nagar, Targhadia- Rajkot, Junagadh, Dediapada, Narmada District and Godhra to learn and understand the technologies at SPRERI.



Fig. 21: Demonstration of technologies during students visit at SPRERI



Fig. 22: Students visit at SPRERI

4.2 MCC Synthesis and Production of Bio-composite from Banana Fibres

Banana being the second most important fruit crop grown in India generates large amounts of lignocellulosic biomass i.e., banana pseudo-stem. Banana fibre, extracted

from banana pseudo-stem, a cellulose-rich by-product, is regarded as an important agricultural waste during the process of banana production. Approximately 220 tons of this is generated from each hectare of banana plantation. Microcrystalline cellulose was successfully prepared from banana fibre using the acid hydrolysis method. Microcrystalline cellulose (MCC) is a partially purified depolymerized non-fibrous form of cellulose. It is a fine, white, odourless, crystalline powder and biodegradable material.

a. Preparation of microcrystalline cellulose (MCC)

Microcrystalline cellulose was successfully prepared from banana fibre using acid hydrolysis method. FTIR spectroscopy of the produced MCC showed that hydrolysis treatments are efficient for the removal of lignin and hemicellulose content. The study proves that microcrystalline cellulose can be directly obtained from the banana pseudo stem which is not only beneficial to reduce the cost of traditional microcrystalline cellulose but is also conducive to the value-added utilization of the pseudo stem.

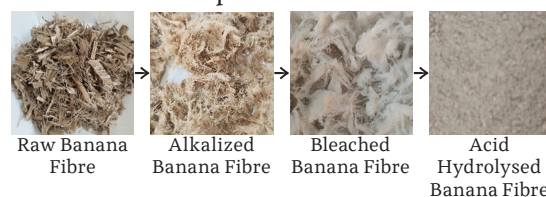


Fig. 23: MCC Production

b. Production of bio-composite:

The potential of MCC in various sectors of research and application is promising and attracting increasing investments. This approach of replacing petroleum-based materials with sustainable renewable resources aims to reduce the negative ecological effects on the environment of polymeric materials. MCC-based composites

contribute favorably to the mechanical behavior of most bio-composites due to their short microfibrils and crystalline nature. MCC-based biofilms were prepared. Since they were to be utilized for food packaging, hence to enhance antibacterial properties, another set of films was prepared embedded with AgNPs.

c. Particle size analysis

The particle size distribution of the powder was measured by photon correlation spectroscopy (PCS) using a Malvern Zetasizer Nano ZS laser particle size analyzer. The instrument was equipped with a He-Ne laser source ($\lambda=633$ nm) and at a scattering angle of 173° . The dispersion concentration was around 0.1 g/L. The suspension was prepared by dispersing the powder in distilled water and filtered through 0.2-micron filter to obtain a well-dispersed suspension and polydispersity index of MCC synthesized from banana pseudo stem.

d. Fourier transform infrared spectroscopy (FTIR):

Figure 24 shows the comparison between FTIR graphs of commercial MCC and MCC obtained from banana fibers. A broad band in the range of $3600-3000\text{ cm}^{-1}$ shows H-bonded-OH groups of cellulose. The absorbance band at 2800 cm^{-1} is specific for MCC and it is the OH & CH stretching of MCC. A band at 1120 cm^{-1} indicates the $-O-C-O$ stretch of 1,4 glycosidic linkage in cellulose. No peaks at 1510 cm^{-1} show the complete removal of lignin.

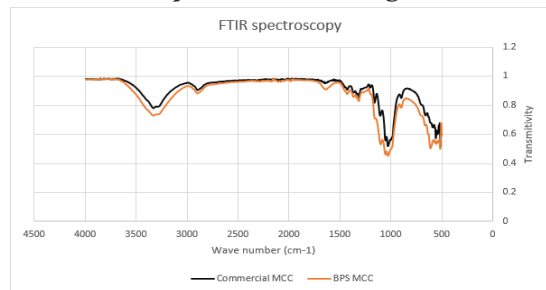


Fig. 24: FTIR spectrum of MCC

e. Antibacterial test for bio-composite:

MCC itself does not show any antimicrobial properties hence MCC is embedded with silver nanoparticles (AgNPs). The antimicrobial bio-composite samples were tested for two strains of bacteria – *Bacillus thuringiensis* (gram positive) and *Klebsiella pneumoniae* (gram negative). The culture was grown in nutrient agar. The bacterial strain was inoculated using spread plate technique and the bio-composite was placed on the agar solution. The samples were incubated overnight (Fig. 25). Table 8 shows the results of antimicrobial tests.



Fig.25: AgNPs embedded bio-composite

Banana fibers are rich in cellulose and thus can be a potential raw material for the preparation of microcrystalline cellulose. The results confirm that one can use a biochemical route for the preparation of MCC. The biochemical route is environmentally safe and minimizes the use of chemicals. The D-glucose mediated bio-reduction process was successfully employed for the rapid impregnation of AgNPs into MCC at ambient conditions. The bio-composite film prepared from AgNPs-impregnated MCC showed antibacterial properties for both gram-positive and negative bacteria.

Table 7: Comparison of Commercial and Banana MCC

S. No.	Properties	MCC prepared from banana fibers	Commercial MCC	Standards as per (USP/IP)
1.	Moisture content (%)	5	5	<10
2.	Starch	0	0	0
3.	pH value	7.42	7	5-7.5
4.	Solubility			
A	Distilled water	Partially soluble	Partially soluble	Partially soluble
B	1% NaOH	Partially soluble	Partially soluble	Partially soluble
C	1% HCl	Insoluble	Insoluble	Insoluble

Table 8: Antibacterial Property of MCC

S. No.	Bacteria	Type of bacteria	Antimicrobial properties	
			MCC with AgNPs	MCC without AgNPs
1	Bacillus thuringiensis	gram positive	Observed	Not observed
2	Klebsiella pneumoniae	gram negative	Observed	Not observed

4.3 CSR Project with GMM Pfadler Foundation

A CSR project from GMM Pfadler Foundation for Implementation of 850–930 nos. of Family Size Improved Bio-mass Cook-stoves (IBCS) for dissemination programme in Gujarat state. The project activity involves replacement of traditional cookstoves with improved cookstoves with higher efficiency biomass-fired cookstoves. The objective of the project was the reduction of biomass consumption which would have been otherwise consumed by less efficient cook stoves.

The CSR support from GMM Pfadler Foundation helped to bridge the gap between the cookstove price and what people can afford by providing partial financial support to stove customers. The cookstove dissemination was carried out on a revolving fund model. This model may not cover the total target area but provides significant resources for a large numbers of beneficiaries. Under this project,

871 cookstoves were disseminated in different provinces of Gujarat. The cookstoves were



Fig. 26: Demonstration and dissemination of SPERITECH cookstoves

disseminated at a 50% reduction in the cost price. Team SPERERI could connect to

more than 3200 rural people through 45 demonstrations in three months.

The impact of the improved biomass cook stove in the project area was assessed by measuring the performance of the traditional stove and the improved biomass stove during the cooking operation. The fuel consumption, cooking time, emission and liberation of suspended particulate matter (SPM) were the main parameters for this study.

The traditional stove (with C-type configuration) offers 8–10% thermal efficiency, whereas SPRERITECH IBCS support the cooking operation with 25 – 27 % thermal

efficiency. Based on the data collected from the project site, meal preparation (lunch and dinner) with a traditional stove for a family (consisting of 4–6 persons) consumes 3 – 3.5 kg of firewood per day. For the same family strength and same meal type, SPRERITECH stove consumes 2.4 – 2.9 kg of firewood, and offers 20% of average wood saving per day as compared to a traditional stove. With 20 % of wood saving, mass dissemination of improved stoves (i.e. 871 stoves) can save ~190 tons of firewood annually, which is equivalent to 48 numbers of average full-grown trees.

Table 9: Comparison of wood consumption of Traditional Cookstove& IBCS

Sr. No.	Description	Wood consumption	Average wood saving
1.	Traditional Stove	3 – 3.5 kg/day	-
2.	SPRERI-Tech IBCS	2.4 – 2.9 kg/day	~ 20%
Average wood saving per day with one family and cookstove			~ 0.6 kg /cook stove /family
Annual wood saving with 871 cook stoves			~ 190 tones (*equivalent to 48 trees)
*an average sized full-grown tree weighs 3–5 tones			
*one tree weighs equivalent to 4 tons of utilizable firewood			

Along with comparatively higher thermal efficiency than the traditional stove, SPRERI-Tech stove offers a higher power rating (~2.6 kW_{th}). The higher power rating, adequate distribution of air in the combustion chamber, ash-discharge facility, and a balanced draft enable uniform heat distribution to the cooking vessel/pot. The resultant effect of all these parameters contributes to the reduction of meal preparation time. It was observed that the average meal preparation time was reduced by 17% with the use of SPRERITECH IBCS.

Carbon monoxide generation is an endothermic process that absorbs the heat of combustion. Each kilogram of CO formed means a loss of 5,654 kcal energy. During the

comparative assessment of both the stove types, their emission profile was captured keeping the same cooking load, time, meal type, and fuel wood. Fig 27 depicts the carbon monoxide (CO) emission profile. It shows

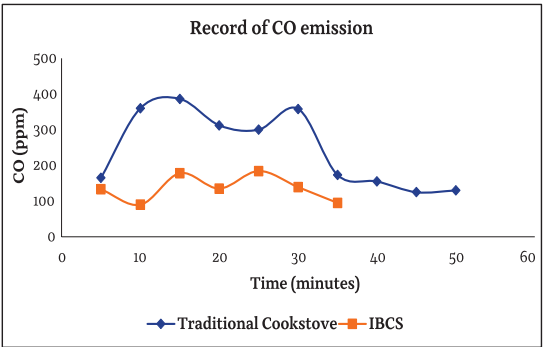


Fig. 27: Comparison of carbon emission from traditional cookstove & IBCS

an increase in CO concentration during the periodic feeding of fresh wood to the stove. Comparatively, SPRERI-Tech IBCS emits 45% lesser carbon monoxide than the traditional stove (Table 10).

Table 10: Comparison of carbon monoxide emission from traditional cookstove & IBCS

Sr. No.	Description	Traditional Stove	SPRE-RI-Tech IBCS	Reduction in CO emission
1.	Carbon Monoxide (CO)	~ 309 ppm	~ 169 ppm	45%



(A)



(B)

Fig.28: Chimney set up for a) traditional chulha, b) Spreritech cookstove

With the collected data during the same meal prepared with both the stove types, it was

observed that SPRERI-Tech IBCS liberates 86% lesser PM₁₀ and 89 % lesser PM_{2.5} (Table 11) compared to the traditional stove. The main reason for less SPM liberation from SPRERI-Tech IBCS is associated with its improved design and ash-removing arrangements.

Table 11: Comparison of particulate emission from traditional cookstove & IBCS

Sr. No.	SPM Levels	Traditional stove	SPRE-RI-Tech IBCS	Reduction in SPM level
1.	PM ₁₀	0.76 mg/m ³	0.10 mg/m ³	86 %
2.	PM _{2.5}	0.79 mg/m ³	0.08 mg/m ³	89 %

Summary of the project

The ‘Triple Bottom line’ concept explains sustainability as the balance or harmony between economic sustainability, social sustainability and environmental sustainability. The project contribution towards sustainable development is established as:

Social Sustainability: The project contributed to the reduction in the drudgery of women and children in rural areas. As reported most of the cooking fuel used is wood and majorly women and children collect fuel from nearby places. Hence reduction in fuel wood consumption gives a sustainable approach to the project. Also time spent and distance travelled for fuel wood collection is reduced. Reduction in firewood requirement would help in spending more time on productive activities such as education, employment etc. According to the literature, there are four stages/sets of activities for collecting fuel for cooking. It includes searching for dried wood, collecting the wood, carrying them to the household, chopping, bundling and stacking the collected wood. On an average, a rural woman spends 40 hours in a month on these

activities.

As SPRERITECH cookstoves save 20% of cooking fuel, it means 8 hours per day can be saved and can be utilized to relax or be spent in other additional income generation activities.

Environmental Sustainability: Cooking on SPRERITECH cookstove as compared to traditional cookstoves results in a 20% reduction in wood consumption. This improves the local environment by reducing the forest degradation /deforestation rate in the project area. Conservation of forests will reduce soil erosion and enhance biodiversity.

Secondly, there is reduction in carbon emission by using SPRERITECH cookstoves. It was expected that one SPRERITECH cookstove would save 7.8 tons of CO₂ saved per year when replaced by wood. Under this project,

871 cookstoves have been disseminated and hence the amount of CO₂ saved per year is 6092 tons, which is equivalent to 48 numbers of average full-grown trees.

Economic Sustainability: Employment opportunities for local communities involved in monitoring, training users, and undertaking periodic maintenance contribute to sustainability. Also, a reduction in the expenditure involved in cooking time will give more opportunities to take up some productive activities.

Health Benefits: The project contributes significantly to improving diseases related to the respiratory system of women and children by reducing smoke in the kitchen, and improving indoor air quality. Also, the SPRERITECH cookstoves are designed in a way that provides a safety grid on the chulha which protects it from burning.

Open House

SPRERI organised its flagship event open house for two days on 24th and 25th of January 2023 with the objective of showcasing the technologies developed at SPRERI. The event was jointly organised by Solar and Extension division. It was a grand event, where the Chief Guest was Shri Meenesh Shah, Chairman, National Dairy Development Board (NDDB) and Er. Shree Bhikhubhai B. Patel Sir, Chairman, Charutar Vidya Mandal (CVM) as the Guest of Honour. A footfall of 2,600 people was noted where students and staff from various schools and

colleges, professionals, entrepreneurs, farmers and others interested in renewable energy visited the institute. A poster competition was also held in which students from different colleges participated and the best three received an award. Everyone who visited SPRERI mentioned that it was a good learning and satisfactory experience. A few farmers interested in certain technologies at the institute also shared their contact details. The event got wide coverage in the local newspapers and electronic media



Fig. 29: Inaugural session of open house



Fig. 30: Demonstration of RET during open house



Fig.31: Team SPRERI at open house

Consultancy Projects

1. Biomass Availability Assessment for Saint Gobain Pvt. Ltd., India

In compliance with the “National Mission on use of Biomass in Thermal Power Plants”, a glass manufacturing company, Saint Gobain Pvt. Ltd., India, wants to introduce biomass as a fuel to solve the issue of air pollution and minimise the carbon footprint of thermal power generation. SPRERI team has earned this opportunity and conducted a biomass assessment study for Saint Gobain’s plant situated in Vishakhapatnam, Andhra Pradesh. The ultimate objective of the study was the planning of a sustainable biomass supply chain in Andhra Pradesh considering Visakhapatnam as the centre. The set benchmark of the study was to plan the availability of 200 metric tons agro-residue on a daily basis. The team has evaluated 20 districts (covering a 300km radius from the plant location) of Andhra Pradesh, Odisha, and Telangana states for biomass availability. During the survey, the team contacted local farmers, Krishi Vigyan Kendra (KVK’s), rice processing plants, bio-fuel manufacturers and traders (i.e., biomass pellets and briquettes) to map the crop-

related data (production, cropping area, crop-to-residue ratio, and tentative biomass availability) along with the contact details. Meanwhile, samples of biomass were collected for analysis. After an assessment of collected data, the team has provided FOR and FOP prices for seasonal biomass available along with the detailed characterization of regionally available biomass.

Performance evaluation of improved biomass cook stove for Adarsh Plant Protect

The team has evaluated various domestic and commercial cook stoves for their performance and power rating in compliance with the BIS and ISO standards for improved biomass cook stoves. The team has tested and evaluated a total of 06 nos. of cookstoves during the year.

Bio-fuel characterization for Dattani Group, Jaipur, Rajasthan

A bio-fuel manufacturer and trader of Jaipur, Rajasthan, India, has submitted their product bio-fuel pellets for detailed characterization. The team has evaluated their product for its proximate, elemental, and ash compositions along with its combustion behaviour and emission profile.

New Facility

1. Thermal Conductivity Determination Machine for PCM

The solar energy division is now equipped with a thermal conductivity determination machine. It will be used to determine thermal conductivity of combination of different PCM’s which are not available in the literature. This setup is equipped with recorder and is suitable for both solid and liquid samples and for the temperature range of ambient to 400°C and thermal conductivity range of 0 to 10 W/mK.



Fig. 32: High-temperature thermal conductivity meter

Recognition & Academic Activities

- B. Tech students, Harshit Kumar Shah and Prakash Damor (Mechanical Engineering Branch, BVM college), interns at TCC Division received 2nd position at Project Expo 2023, organised by CVM. *“Development of a continuous bio-sorbent system for the treatment of bulk milk chiller effluents.”*
- Dr. Geeta Kumari was selected for ITS, Young Scientist Scheme to present a paper at AIChE annual meeting, held in Phoenix, Arizona, USA. *“Oxidative Fast Pyrolysis of Groundnut Shell (GNS) in the Catalytic and Non-Catalytic Mode for Biofuel Production.”*
- Dr. Geeta Kumari was the speaker on the webinar “Description: Research on Thermochemical Conversion” Organized by: Parul Institute of Technology, Parul University.

Graduate & Post-graduate Dissertation

Student	Institute	Programme	Duration	Division	Research Topic
Mr. Saket Fulkeria	C.L. Patel Institute of Studies and Research in Renewable Energy (ISRRE), CVM University	M.Sc. Renewable Energy	July 18 to December 18, 2022.	Solar Energy Division	Performance evaluation of PCM based thermal energy storage system for cooking
Mr.Kathan Sejalben Shah	BVM Engineering College, Sardar Patel University	Bachelor of Mechanical Engineering	December 27, 2022 to April 29, 2023	Solar Energy Division	Numerical Analysis of Heat Transfer Between PCM based Thermal Energy Storage and Solar Powered Cold Storage
Mr. Rudrakumar Jayantibhai Patel	Government Engineering College (GTU), Valsad	Bachelor of Mechanical Engineering	January 23, 2023 to April 17, 2023	Solar Energy Division	Performance Evaluation of Thermal Storage Integrated Solar Driven Cold Storage
Mr. Kalpesh Pravinbhai Zinzuvadiya	Government Engineering College (GTU), Valsad	Bachelor of Mechanical Engineering	January 23, 2023 to April 17, 2023	Solar Energy Division	Performance Evaluation of Thermal Storage Integrated Solar Driven Cold Storage

Student	Institute	Programme	Duration	Division	Research Topic
Mr. Harin Babubhai Radadiya	Government Engineering College (GTU), Valsad	Bachelor of Mechanical Engineering	January 23, 2023 to April 17, 2023	Solar Energy Division	Performance Evaluation of PCM filled Thermal Energy Storage Device for Cooking Application
Mr. Lakshman Dath	Central University of Jharkhand	M.Tech of Energy Engineering	August 2022 – May 2023	Thermo-chemical Conversion Technology	Biomass assessment study for Vishakhapatnam and utilization of biomass for steam generation in boiler
Mr. Harshit Kumar Shah	BVM Engineering College, Vidyanagar	Bachelor of Mechanical Engineering	December 2022 – April 2023	Thermo-chemical Conversion Technology	Performance evaluation of continuous bulk milk chiller effluents treatment apparatus
Mr. Prakash Damor	BVM Engineering College, Vidyanagar	Bachelor of Mechanical Engineering	December 2022 – April 2023	Thermo-chemical Conversion Technology	Performance evaluation of continuous bulk milk chiller effluents treatment apparatus
Mr. Smith Parekh	Government engineering collage, Valsad	Bachelor of Chemical Engineering	January 2023 – May 2023	Thermo-chemical Conversion Technology	Feasibility assessment of banana tree waste pyrolysis
Mr. Dev Parmar	Government engineering collage, Valsad	Bachelor of Chemical Engineering	January 2023 – May 2023	Thermo-chemical Conversion Technology	Feasibility assessment of banana tree waste pyrolysis
Mr. Hunny Gohil	Collage of agricultural engineering, Godhara	Bachelor of Agricultural Engineering	July 2023- Nov 2023	Thermo-chemical Conversion Technology	Feasibility assessment of bulk milk chiller effluents treatment in batch mode
Mr. Jayendra Solanki	Collage of agricultural engineering, Godhara	Bachelor of Agricultural Engineering	July 2023- Nov 2023	Thermo-chemical Conversion Technology	Groundnut shell pyrolysis study in a pilot scale continuous pyrolysis system
Mr. Anshul Padhya	Collage of agricultural engineering, Godhara	Bachelor of Agricultural Engineering	July 2023- Nov 2023	Thermo-chemical Conversion Technology	Feasibility study of air gasification of biomass derive char

Publications

1. Sojitra M, Gupta S, Tiwari A K, Joshi A K, Singh R, (2023), "CFD Simulation of Portable Thermal Storage Device for Solar Cooking System", Proceedings of International conference on Advances in Clean Energy and Sustainability 2022, Green Energy and Technology. Springer Nature, Singapore, (pp. 529–538)
2. Parmar M., Soni B., Shah A.J., Karmee S.K, (2022), "Pyrolysis of pellets prepared from groundnut shell and crude glycerol: in-situ utilization of pyro-gas and characterization of products", *Detritus* (pp 1–12) DOI: 10.31025/2611-4135/2023.17254.

Conferences, Meetings & Workshops

International Conferences

- Kumari G, Soni B, "Oxidative Fast Pyrolysis of Groundnut Shell in the Catalytic and Non-Catalytic Mode for Biofuel Production", presented in annual meeting of American Institute of Chemical Engineers (AIChE), held at Phoenix, Arizona, USA, on November 13–18, 2022.
- Patel A, Vachhani H, Soni B, Kumari G, "Activated Carbon Production from Groundnut Shell char via. Chemical Activation: A Pilot-scale Study", presented in, International Conference on Technological Interventions for Sustainability CHEM-CONFLUX22 organized by the MNNIT, Allahabad and University Sains Malaysia on April 14–16, 2022.
- Ramachandran S, "Cooling Load Prediction of an off-Grid Solar Under-Ground Cold Storage: A TRNSYS Perspective", presented in International Conference on Innovations in Clean Energy Technologies (ICET 2023), Energy Centre, MANIT-Bhopal, on April, 9, 2023.

Workshop

S. No.	Details of the programme	Date	Scientist, research staff/ Student
1.	The European Union India Innovation Cooperation in Biofuels Sector; Awareness event at Pandit Deendayal Energy University (PDEU), Ahmedabad.	February 13, 2023	Dr. Geeta Kumari
2.	Webinar on "Empowering Women in Waste Management", supported by the Blue Planet Environmental Solution.	February 24, 2023	Dr. Geeta Kumari Dr. Barnali Bhui
3	Webinar on "Harnessing the Bio-Energy Opportunities in India" Organized by, Indian Biogas Association.	June 15, 2022	Dr. Geeta Kumari, Er. Bhavin Soni, Er. Urvish Patel, Er. Shardul Amin
4	Attended one-week high-end workshop on "Sophisticated Analytical and testing instrument", Organized by the Department of Energy and Environment, National Institute of Technology, Tiruchirappalli.	January 23–27, 2023	Er. Milan Sojitra, Ms. Drishya PK

S. No.	Details of the programme	Date	Scientist, research staff/ Student
5	8th Annual Review Workshop of Consortia Research Platform on Energy from Agriculture, Farming and Micro Irrigation System	January 24, 2023	Dr Geeta Kumari, Dr. Barnali Bhui, Er. Bhavin Soni, Er. Urvish Patel
6	XXVI Workshop of All India Coordinated Research Project on “Energy in agriculture and agro-based industries” organized by CIAE, Bhopal	December 20 – 22, 2022	All scientific staff of BCT, SED, TCCT & Extension division
7	3 day workshop on “Livelihood training and activities” organised by Vigyan Ashramat JP Naik Centre for Education (Kothrud, Pune)	November 5–7, 2022	Dr. Amrita Doshi

Meetings

S. No.	Details of the programme	Date	Scientist/Research staff
1	Virtual meeting regarding “Upgrading of RTC labs for Solar Thermal Testing of ETC solar collectors as per prevailing BIS standard” organized by MNRE	July 26, 2022	Er. Asim Joshi
2	Virtual meeting on MNRE lab policy for Solar Water Heating system & quality control order” organized by Solar Thermal Federation of India, Pune	July 27, 2022	Er. Asim Joshi
3	Meeting with MNRE and solar water heater stakeholders at RTC-Pune, Centre for Energy Studies, Savitribai Phule Pune University, Pune	February 08, 2023	Dr. Gaurav Mishra and Er. Asim Joshi
4	Expert committee review meeting on completed projects of the strategic area “Farm Mechanization and Energy” of NASF and presented progress report on “Solar-biogas hybrid refrigeration system” of National Agricultural Science Fund – ICAR	February 08, 2023	Er. Asim Joshi

Expert Lecture

S. No.	Details of the programme	Date	Scientist/ Research staff
1	Expert Lecture on “Designing of Solar PV plant” at the Mechanical Engineering Department, G H Patel College of Engineering and Technology, Vallabh Vidyanagar	October 14, 2022	Er. Asim Joshi
2	Expert lecture on “Utilization of solar energy” to mechanical engineering graduate students at The Maharaja Sayajirao University of Baroda, Vadodara	September 29, 2022	Er. Milan Sojitra
3	Participated in Charutar Vidya Mandal University Hackathon–2023 as evaluator, organized by A.D. Patel Institute of Technology	March 17-18, 2023	Er. Milan Sojitra

Visitors

- 30 pedagogic faculty members from the Mechanical Engineering Department, Institute of Technology, Nirma University visited SPRERI as a part of ISTE approved two-week STTP on “Recent Trends in Renewable Energy Systems” for the continuous review of the teaching-learning process, including curricula, pedagogy, and assessment.
- A quartet of nerdy from Saint Gobain visited SPRERI to understand the technologies of the institute and their possible implementation in the field in their premises.
- Mr. Dilip Patel from AD Consult and Engineering Ltd (based in UK) visited SPRERI. He was BVM Graduate and appreciated the ongoing research and extension work at SPRERI. Mr. Patel also offers online courses on Energy storage Fundamentals for Energy Security.
- Team from Alembic Pharmaceuticals Limited visited SPRERI to understand the technologies of the institute and their possible implementation in the field at their location.

Industry Visits and Surveys

1. Er. Asim Joshi and Er Bhavin Soni visited M/s Parth Electronics Pvt Ltd, Vithal Udyognagar on November 18, 2022, for a discussion on Technology transfer for SPRERITECH solar refrigerator and Biomass cookstove.
2. Er. Asim Joshi and Mr. Paresh Mer visited M/s Satva organic, Boriavi on November 21, 2022, for a discussion on the installation of a walk-in type solar tunnel dryer on a cost-sharing basis.
3. Er. Asim Joshi and Mr. Paresh Mer visited Sarthi Sanstha, Godhar on November 24, 2022, for a discussion on the installation of a walk-in type solar tunnel dryer on a cost-sharing basis.
5. Dr. Gaurav Mishra & Er. Asim Kumar Joshi visited the on-site testing facility for solar evacuated tube and integrated water heating system at RTC-Pune, Centre for Energy Studies, Savitribai Phule Pune University, Pune on February 08 & 09, 2023.
6. Meeting with NDDDB regarding consultation of Biogas plant installation and utilization of solid and liquid waste from plant as fertilizer and other value added products.
7. Meeting with Shree Vadodara Distt. Co-op. Sugarcane Grower’s Union Ltd. For installation of Biogas/bioCNG plant and utilization of press mud as feedstock for Biogas production
8. Meeting with Advait Infra for discussing scope of Biohydrogen Production from municipal solid waste and dairy wastewater

Director

- Dr. Gaurav Mishra

Solar Energy Division

- Er. Asim Kumar Joshi, In-charge
- Dr. Siddharth Ramachandran
- Mr. Mahendra Padhiyar
- Er. Milan Sojitra
- Mr. Mukesh Jadav
- Dr. Sachin Gupta (up to 13.06.2022)

Bio-conversion Technology Division

- Dr. Maku Venkata Rohith
- Mrs. Aesha Patel
- Mr. Harmar Parmar
- Mr. Ashok Mochi
- Mrs. Manjula Vadhel
- Dr. Madhuri Narra (up to 03.09.2022)
- Dr. Shaishav Sharma (up to 01.10.2022)
- Mr. Alok Sivaprasad Vishwakarma (up to 19.11.2022)
- Dr. Neha Singh
- Dr. Shyamali Sarma (up to 31.01.2023)
- Ms. Drishya PK
- Ms. Nidhi Patel (up to 07.10.2022)
- Mr. Ashok Harijan

Thermo-Chemical Conversion Technology Division

- Dr. Geeta Kumari, In-charge
- Er. Urvish Patel
- Mr. Ashok Patel
- Dr. Barnali Bhui
- Er. Bhavin Soni

Technology Transfer and Extension Division

- Dr. Amrita Doshi, In-charge
- Mr. Paresch Mer
- Mr. Shailesh Solanki
- Mr. Minesh Suthar
- Er. Samir Vahora (up to 12.09.2022)

Administration

- Mr. Bipin K. Patel
- Mr. Hasmukh Vaghela
- Mr. Dahya Harijan
- Mr. Ramesh Bhai
- Mr. Rahesh Machhi
- Ms. Pragna Dave (up to 10.02.2023)
- Mr. Bhupendra Parmar
- Mr. Ishwar Harijan (up to 31.05.2022)
- Mr. Chetan R. Parmar

Balance Sheet

B. C. PATEL & CO.
Chartered Accountants

1 Desai Building
Maifer Road, Anand - 38001
Ph. No. (02692) 244893

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE - VALLABH VIDYANAGAR BALANCE SHEET AS ON - 31 - 03 - 2023

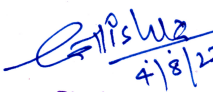
FUNDS & LIABILITIES	31/03/2022	31/03/2023	ASSETS	31/03/2022	31/03/2023
CAPITAL FUND	₹ 1,082,669.20	₹ 1,082,669.20	FIXED ASSETS		
PROJECT FUND			1. Furniture & Fixtures	₹ 249,808.62	₹ 249,808.62
Balance from last year	₹ 29,249,245.67	₹ 17,166,925.67	2. Electric Fittings	₹ 162,350.85	₹ 162,350.85
Add / Less during the year	-₹ 12,082,320.00	-₹ 6,839,716.00	3. Mobile Phone	₹ 19,600.00	₹ 19,600.00
(As per Schedule - 4)	₹ 17,166,925.67	₹ 10,327,209.67	4. Institute Equip.(R & D / Others)	₹ 1,071,372.00	₹ 1,071,372.00
PROJECT EQUIPMENT			5. Car - GJ-23 AF-0282	₹ 585,597.00	₹ 585,597.00
Depreciated value of Equipment	₹ 113,932,228.51	₹ 126,748,051.51	6. New Jeep - GJ-23-GA-0488	₹ 834,000.00	₹ 834,000.00
Add : During the year	₹ 12,815,823.00	₹ 2,594,308.00		₹ 2,922,728.47	₹ 2,922,728.47
(As per Schedule - 1)	₹ 126,748,051.51	₹ 129,342,359.51	PROJECT EQUIPMENT	₹ 126,748,051.51	₹ 129,342,359.51
Gratuity Fund	₹ 8,645,687.20	₹ 6,643,040.32	INVESTMENT		
EAR MARKED FUND			Fixed Deposit (As per Schedule -2)	₹ 29,744,960.68	₹ 32,241,414.00
1. Building Fund Provision	3364376	3532595	Deposit in LIC - Gratuity Scheme	₹ 8,645,687.20	₹ 6,643,040.32
2. Research & Development Fund	9469817.83	10460434.83		₹ 38,390,647.88	₹ 38,884,454.32
3. Contingent Development Fund	133400	140070	LOANS & ADVANCES		
4. Depreciation Fund	6435253.3	6884896.3	1. Tax Deduction at Source	₹ 744,340.06	₹ 793,505.06
5. Endowment Fund (Hari Om Ashram)	₹ 1,442,017.75	₹ 1,514,118.75	2. Telephone Deposit	₹ 20,313.00	₹ 20,313.00
6. Share & Care Fund	₹ 152,835.00	₹ 160,477.00	3. CGM Deposit(Oil Diesel & Petrol)	₹ 12,400.00	₹ 12,400.00
7. Maint. Fund (Core Grant)	₹ 725,879.00	₹ 762,173.00	4. Indian Oxyzen Ltd., Deposit	₹ 4,252.94	₹ 4,252.94
8. Depreciation Investment Fund	₹ 455,244.00	₹ 478,006.00	5. Mobile Phone Deposit	₹ 4,680.00	₹ 4,680.00
9. Staff Welfare Fund	₹ 951,774.95	₹ 1,540,642.95	6. Broad Band Security Deposit	₹ 3,000.00	₹ 3,000.00
10.Quiz Prog. Fund	₹ 58,262.00	₹ 61,175.00	7. Gas Cylinder Deposit	₹ 10,350.00	₹ 10,350.00
11.Donation (Gen.)	₹ 1,936,101.00	₹ 2,172,674.00	8. Security Deposit(GEB - New DP)	₹ 100,920.00	₹ 100,920.00
(As per Schedule - 5)	₹ 25,124,960.83	₹ 27,707,262.83	9. Loan to Staff & Advance to Project	₹ 729,642.00	₹ 729,642.00
			10.Intrest Accrued	₹ 544,069.01	₹ 609,922.00
Balance as per last Balance Sheet				₹ 2,173,967.01	₹ 2,288,985.00
Balance as per last Balance Sheet	-₹ 15,680.85	-₹ 31,577.65	BALANCE :		
Add/ Less : - As per Inc.& Exp. A/c	-₹ 15,896.80	₹ 45,784.45	Bank Balance (As per Schedule - 3)	₹ 8,266,713.89	₹ 1,631,948.03
Add:- Surplus	₹ 31,577.65	₹ 14,206.80	Cash Balance	₹ 234,608.00	₹ 46,273.00
				₹ 8,501,321.89	₹ 1,678,221.03
TOTAL	₹ 178,736,716.76	₹ 175,116,748.33	TOTAL	₹ 178,736,716.76	₹ 175,116,748.33

Date :- 02/08/2023

Place :- Vallabh Vidyanagar


Accounts Officer
Sardar Patel Renewable Energy Research Institute




4/8/23
Director
Sardar Patel Renewable Energy Research Institute




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

Acronyms

ATAL	AICTE training and learning
CFD	Computational fluid dynamics
DAM	Direct absorption mode
DPM	Diesel particulate matter
FDP	Faculty development programme
H ₂ O	Water
Hex	Heat Exchanger
HTM	Heat transfer mode
LiBr	Lithium-Bromide
LPG	Liquefied petroleum gas
NaNO ₃	Sodium Nitrate
PCM	Phase change material
PTS	Portable thermal storage
PV	Photovoltaic
SC	Steering Committee
SCM	Steering Committee Meeting
STTP	Short-term training programme
VabM	Vapour absorption machine/chiller
VadM	Vapour adsorption machine/chiller
VCRM	Vapour compression refrigeration system
VFD	Variable frequency drive

List of Technologies for Commercialization

- Thermal battery-based solar refrigerator
- Standalone type PV integrated solar low tunnel dryer
- Forced circulation solar cabinet dryer
- Thermal energy storage-based Indirect solar dryer
- Solar-based wax melting system
- Single-axis sun tracker for photovoltaic panels
- Solar-biogas hybrid cold storage system
- Portable double-glazed solar dryer
- Single-axis sun tracker for photovoltaic panels
- Solar PV-driven thermal energy storage integrated micro cold storage
- Thermal energy storage integrated solar concentrating dish-based cooking system
- Thermal energy storage integrated solar Fresnel lens-based cooking system
- Solar evacuated tube with heat pipe-based desalination system
- Solar evacuated tube with heat pipe collector-based pressure-cooking system
- Thermal energy storage integrated Solar concentrating cooking system
- Solar photovoltaic-thermal (PVT) hybrid collector for air heating
- Thermal energy storage based Indirect solar dryer
- Nanofluid for performance enhancement of solar thermal collectors
- Conversion of fruit and vegetable residue to bio-gas and manure
- Conversion of kitchen residue to bio-gas and manure
- Biogas 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 the tribal rural house

Acknowledgments

SPRERI greatly acknowledges the financial support it continues to receive from:

- Indian Council of Agricultural Research (ICAR), GoI
- Department of Biotechnology (DBT), GoI
- Ministry of New and Renewable Energy (MNRE), GoI
- Department of Science & Technology (DST), GoI
- Tata Trust, Mumbai
- Department of Energy and Petrochemicals (EPD), GoG, Gandhinagar
- Gujarat Energy Development Agency (GEDA), Gandhinagar
- Gujarat Council of Science & Technology (GUJCOST), Gandhinagar
- Gujarat State Biotechnology Mission (GSBTM), Gandhinagar
- Jharkhand Tribal Development Society (JTDS), Jharkhand



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