

ANNUAL REPORT 2023-24



SPRERI
Striving for Excellence



SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE

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	Page
<i>List of Figures</i>	... I
<i>List of Tables</i>	... III
<i>Highlights of the Year</i>	... IV
<i>The Organization & Structure</i>	... V
<i>Vision and Mission</i>	... VI
<i>Board of Management</i>	... VII
1. Solar Energy Division	... 1
2. Bio-conversion Technology Division	... 6
3. Thermo-chemical Conversion Technology Division	... 11
4. Hydrogen Generation	... 16
5. Technology Transfer and Extension Division	... 18
6. Open House	... 23
7. Consultancy Services	... 24
8. Activities/Events	... 24
9. New Initiatives	... 26
10. Memorandum of Understanding	... 28
11. Recognition and Academic Activities	... 28
12. Publications	... 29
13. Conferences, Workshops, Meetings & Invited Talks	... 29
14. Trainings/Internships/Dissertations	32
15. Visitors	... 35
<i>The Team</i>	... 36
<i>Balance Sheet</i>	... 37
<i>Acronyms</i>	... 38
<i>Technologies for Commercialization</i>	... 39
<i>Acknowledgements</i>	... 40

List of Figures

- Figure 1 : Solar walk-in type dryer installed at M/s CZ Patel & Sons, Boriavi village, Gujarat (Left) and Methi leaves loaded in the dryer (right)
- Figure 2 : Temperature profile of dryer without load
- Figure 3 : Day-wise reduction in weight of fenugreek during drying with load
- Figure 4 : Cold room with banana arranged in crates for load testing
- Figure 5 : Temperature profile observed during load test
- Figure 6 : Images of raw banana (left) and ripe banana (right)
- Figure 7 : Temperature profile of refrigerator
- Figure 8 : Up-scaled solar DC refrigerator with thermal backup
- Figure 9 : Vacuum filtration unit
- Figure 10 : Nanofluid samples (a) right after preparation and (b) after two months of storage
- Figure 11 : (a) UV-Vis absorbance spectrum for prepared nanofluid (b) particle size distribution
- Figure 12 : Schematic of solar-thermal based steam distillation system (left), extracted essential oil from eucalyptus leaves (right)
- Figure 13 : Schematic for sorbitol production from agro-waste process
- Figure 14 : Microalgae experiments for flue gas sequestration
- Figure 15 : (a) AgNPs impregnated MCC powder (b) MCC based composite films using PVA (c) Antimicrobial activity of AgNP based MCC composite film
- Figure 16 : Lignin and cellulose nanocomposite films (a) lignin film prepared by solvent casting method, (b) lignin film by electrospinning method, (c) SEM image of lignin film, (d) cellulose film by solvent casting method, (e) cellulose film by electrospinning method, (f) SEM image of cellulose film
- Figure 17 : Biomass and lipid profile of newly isolated strains
- Figure 18 : Capsulated SPRERITECH bacterial and fungal strains
- Figure 19 : Fluidized bed gasification system installed in Poha making industry
- Figure 20 : Schematic diagram of steam generation system integrated with fluidized bed gasification system
- Figure 21 : Fluidized bed oxidative fast pyrolysis system used for utilization of banana tree waste
- Figure 22 : Schematic of the biomass ash based carbon capture setup
- Figure 23 : A typical LCA framework (ISO: 2006)
- Figure 24 : Mass and energy balance for torrefaction process
- Figure 25 : System boundary and permanent flow for torrefaction process of biomass
- Figure 26 : Hydrogen gas production in 5 L fermenter
- Figure 27 : Concept diagram of hydrogen production by Water Gas Shift Reactor

- Figure 28 : Data showing districts covered, number of beneficiaries, villages covered and number of beneficiaries in each village during demonstrations
- Figure 29 : Renewable energy technology demonstration at Kanjari
- Figure 30 : SPRERITECH cookstove demonstration at Mothirath village
- Figure 31 : Students attending the expert session
- Figure 32 : Demonstration of technologies at SPRERI
- Figure 33 : Training programme on Renewable Energy and Energy Technology
- Figure 34 : Interaction with team SPRERI during educational visit
- Figure 35 : Preparation of inoculum for rice straw composting
- Figure 36 : Mixing of rice straw and inoculum
- Figure 37 : Cookstove demonstration to SC community
- Figure 38 : Data showing districts and villages covered and number of cookstoves and micro solar domes distributed to the SC community
- Figure 39 : Inauguration programme of Open House
- Figure 40 : Demonstration of technologies during Open House
- Figure 41 : Biomass briquettes & pellets quality awareness event at Navsari, Gujarat
- Figure 42 : Students presenting poster in the poster paper competition
- Figure 43 : Prize distribution after the poster paper competition
- Figure 44 : Exhibition stall during the exhibit at SPRERI campus
- Figure 45 : Inauguration of the library by the SPRERI Director (left); and Visitors to the library (right)
- Figure 46 : Hydrogen research laboratory equipped with hydrogen production technologies
- Figure 47 : Waste-to-Value process flow
- Figure 48 : First edition of SPRERI e-Newsletter

List of Tables

- Table 1 : Test results for cooking using thermal storage device
- Table 2 : Temperature values observed during load test
- Table 3 : Sorbitol production from various metal oxides and catalysts in GAA acid
- Table 4 : Total lipid and PUFA content in oil extracted from microalgae
- Table 5 : Properties of biochar prepared and its comparison with Indian coal
- Table 6 : Impact analysis of 100 kg/day torrefaction process unit for rice straw
- Table 7 : Hydrogen production and yield from newly isolated bacterial strains



Highlights of the Year

The past year has been transformative for Sardar Patel Renewable Energy Research Institute (SPRERI), marked by significant progress in research, development, and implementation of sustainable energy solutions. The institute's commitment to environmental conservation, energy efficiency, climate change mitigation, and sustainable development has advanced its efforts toward achieving the Sustainable Development Goals (SDGs). Guided by Mahatma Gandhi's belief that *"The future depends on what we do in the present,"* the organization has made notable strides in solar, biochemical, and thermochemical technologies.

The Solar Energy Division has achieved significant advancements by improving solar energy devices like solar dryers and refrigeration systems. They have also enhanced the thermal conductivity of heat collectors through nano-fluids. Additionally, they have developed user-friendly indoor solar cooking solutions. Moreover, the division is extending solar energy applications to the aroma industry, focusing on essential oil extraction from aromatic and medicinal plants. This innovation promises to enhance the quality and yield of extracts while reducing carbon emissions compared to traditional fossil fuel methods.

The Biochemical Conversion Division has made significant progress by developing cellulose-based antibacterial nano-biocomposites from agricultural waste and extracting lignin from banana and rice straw. They have also produced sorbitol from the microcrystalline cellulose (MCC) using a range of acids and metal oxides.

The Thermochemical Conversion Division successfully integrated the SPRERITECH fluidized bed gasification system with a fuel-flexible commercial steam generation system, achieving 48% reduction in fuel costs. They also worked on producing bio-oil and biochar from banana waste via pyrolysis, showing fuel properties comparable to Indian coal.

Recognizing green hydrogen as a crucial technology for decarbonization, SPRERI has set up a specialized Green Hydrogen Production Research Laboratory to conduct advanced research across the entire hydrogen value chain, including production, storage, transportation, and end-use. The laboratory places a strong emphasis on developing and localizing various hydrogen technologies and their components. Its goals are to drive the green energy transition through innovative solutions, promote interdisciplinary collaborations, and offer training opportunities for emerging professionals. Presently, the lab is equipped with Biomass gasification integrated with water gas shift reactor for hydrogen generation, Bio-hydrogen through dark fermentation.

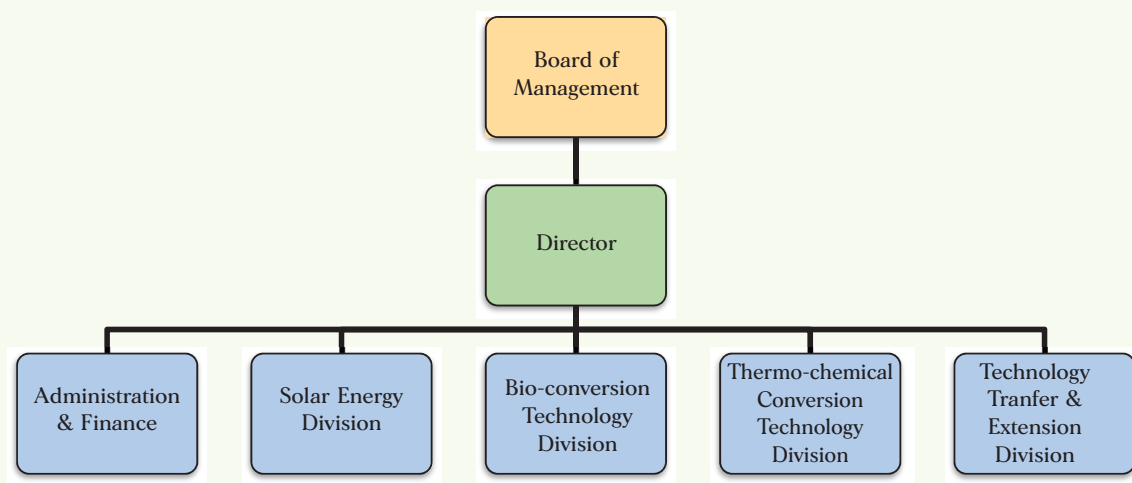
The Technology Transfer and Extension Division has greatly broadened its outreach efforts by actively engaging with communities and promoting awareness of renewable energy technologies. As part of the SCSP program, supported by ICAR-AICRP on EAAI, the division has carried out over 60 demonstrations and distributed 471 cookstoves and 20 Micro Solar Domes to the scheduled caste (SC) community in Gujarat. Furthermore, the division has organized 35 one-day training programs on "Renewable Energy and Energy Conservation," with support from Gujarat Energy Development Agency (GEDA), Government of Gujarat.

SPRERI has also launched a new initiative aimed at achieving a zero-waste sustainable campus by transforming campus waste into valuable products like biochar and pellets. The institute held its flagship event, the 15th Open House, on February 28th and 29th, 2024, to highlight the latest advancements in renewable energy technologies. The event attracted 2,600 attendees, including students, farmers, women from self-help groups, technocrats, and local residents from various districts of Gujarat.

SPRERI's dedication to create efficient and cost-effective energy solutions is paving the way for a brighter and more sustainable future.

The Organization & Structure

SPRERI, established in 1979, is an autonomous and not-for-profit organization managed by Board comprising leading technologists, scientists, industrialists, and representatives of Central and State Governments. It is recognized by the Department of Science and Industrial Research, Government of India, as a scientific and Industrial Research Organization. It is also approved as a Research Association for the purpose of clause (ii) of sub-section (I) 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 academic institutions and universities. Solar energy, bio-conversion and thermo-chemical conversion of biomass are three major thrust areas of research at SPRERI. Many renewable energy devices and systems developed at SPRERI are now manufactured by selected industries and supplied to end users. In addition, the promotion of renewable energy technologies is pursued through field evaluation and demonstrations, training and entrepreneurship development, awareness programmes and integrated development of selected tribal villages.



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 development 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

Dr. Amrita Patel : Trustee, Charutar Arogya Mandal, Karamsad, Anand
Chairperson

Shri Er. Bhikubhai B Patel : Chairman, Charutar Vidya Mandal, Vallabh
Working Chairman Vidyanagar, Anand

Members

Shri Manish S. Patel : Vice-President, Charutar Vidya Mandal, Vallabh
Vidyanagar, Anand

Dr. S.G. Patel : Hon. Secretary, Charutar Vidya Mandal, Vallabh
Vidyanagar, Anand

Mr. Sydney Lobo : Senior Technical Advisor, Clean Tech Space, Mumbai

Dr. Datta Madamwar : Scientific Advisor, P.D. Patel Institute of Applied
Sciences, Charotar University of Science and
Technology, CHARUSAT Campus, Changa

Dr. K. Narsaiah : Assistant Director General (Process Engg) Indian
Council of Agricultural Research, New Delhi

Ms. Bhaktiben Shamal : Joint Secretary (NCE), Department of Energy &
Petrochemicals, Gandhinagar

Dr. D.K. Tuli : Former ED IOC (R&D); CEO Indian Oil, Technologies
Ltd., Faridabad

Prof. Satish B. Agnihotri : Professor, Indian Institute of Technology Bombay,
Powai, Mumbai

Mr. Apoorva Oza : Chief Executive, Aga Khan Rural Support Programme,
Ahmedabad

Dr. Anuradda Ganesh : Chief Technical Advisor and Director, CUMMINS
Technologies India Limited, Pune

Dr. Anil Kumar Dubey : Director, SPRERI, Vallabh Vidyanagar

Member-Secretary

1.1 Solar cooking

Solar cooking integrated with thermal storage for day-night operation

A compact and portable thermal storage device was developed, featuring a stainless steel (SS) casing filled with phase change material (PCM). The device was heated up to 350°C and tested for water boiling, achieving an efficiency of approximately 42%. Cooking tests were conducted to boil rice and lentils after charging the thermal storage device at temperature ranging from 200 to

350°C. The results, detailed in Table 1, were promising for indoor cooking. When charged to temperatures between 200 and 300°C, the device effectively cooked 200 g (dry weight) of rice and lentils in a single charge, sufficient for a family of four. Economic analysis indicated that the system has a simple payback period of 5.5 years without subsidy and 4.7 years with a 30% subsidy on a solar concentrating system, making it a viable alternative to liquefied petroleum gas (LPG) costs.

Table 1: Test results for cooking using thermal storage device

Charged Temp. level	Number of batches	Quantity of Rice (g (dry wt.))	Quantity of Dal (g (dry wt.))	Water used for cooking (g)	Cooking time recorded (min)
200	3	200	200	500	196
250	4				255
300	4				238
350	5				125

1.2 Solar drying

Walk-in type solar tunnel dryer

A walk-in type solar tunnel dryer was installed on the terrace of a warehouse belonging to M/s CZ Patel & Sons in Boriavi village, Gujarat, with the user's contribution of 60% of the cost. This system was set up to dry various organic farm produce, including turmeric, ginger, potato chips, and fenugreek leaves. The installed dryer, shown in Figure 1, measures 7 m x 4.25 m x 1.95 m (L x B x H) and is equipped with a relative humidity-

based controller and timer to automatically regulate the fans and maintain optimal humidity levels during the day. Under no-load conditions, the temperature inside the dryer was observed to reach up to 50°C with an average Global Horizontal Irradiance (GHI) of 231 W/m², as depicted in Figure 2. The system was tested with 9.30 kg of fenugreek leaves (Figure 1). The drying process, which lasted for three days due to cloudy conditions, resulted in a final dried product weight of 1.4 kg. Further testing of the system is ongoing.



Figure 1: Solar walk-in type dryer installed at M/s CZ Patel & Sons, Boriavi village, Gujarat (left) and Methi leaves loaded in the dryer (right)

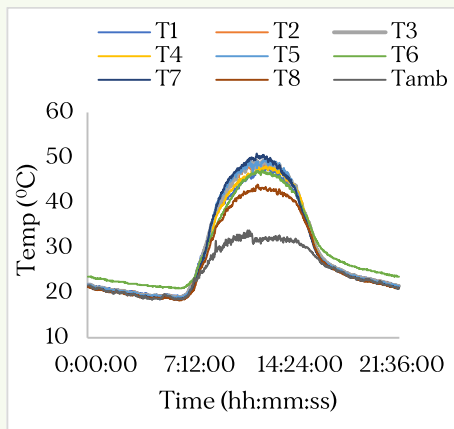


Figure 2: Temperature profile of dryer without load

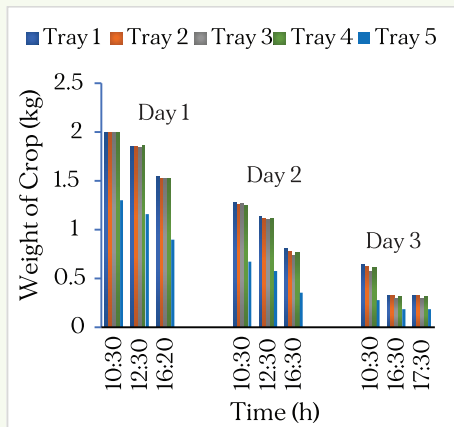


Figure 3: Day-wise reduction in weight of fenugreek during drying with load

1.3 Solar refrigeration

Solar PV driven micro cold storage

Thermal storage was integrated with PV driven micro cold storage as shown in Figure 4. The system was tested for ripening of 500 kg banana on solar photovoltaic (PV) with thermal backup for night time temperature maintenance. The cold room with banana

Table 2: Temperatures values observed during load test

Parameter	Average	Minimum	Maximum
Ambient	20.3	14.5	28.5
Load temperature	14.4	12.5	16.7
TES temperature	10.1	6.5	15.4

arranged in crates is shown in Figure 4. The test was carried out for 5 days with cold room set temperature of 15°C. During the test, the refrigerant circulated through both the evaporator line and the thermal energy storage device concurrently. Temperature control mechanism was employed to operate the cold room fans and the fans of the thermal energy storage device, ensuring the regulation



Figure 4: Load test of cold room with banana

of the cold room temperature throughout the test period. The temperature profile observed is shown in Figure 5. During the test the relative humidity was maintained in the range $90 \pm 5\%$. The details on temperature of load, thermal energy storage (TES) and ambient are given in Table 2. The images of raw banana (initial stage) and after ripening (after 5-days) are given in Figure 6. It was observed that due to the thermal storage the temperature of cold room was well maintained near the set temperature. Further improvement of the system is in progress.

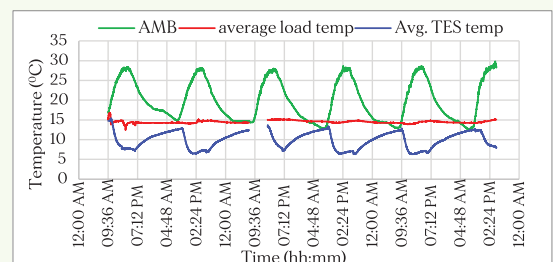


Figure 5: Temperature profile observed during load test



Figure 6: Images of raw banana (left) and ripe banana (right)

Up-scaled solar refrigerator

An in-house made refrigerator with a capacity of 180 L was first tested with water to assess its cooling performance, power consumption and the time required to reach 0°C. The refrigerator was integrated with a 210 W DC compressor. The time taken by water to reach

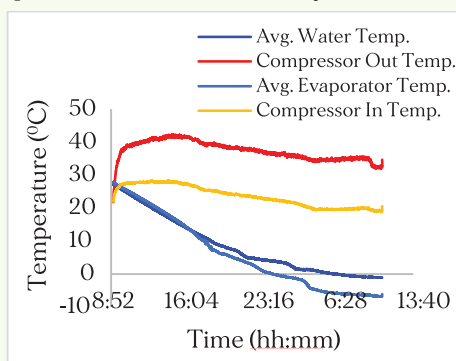


Figure 7: Temperature profile of refrigerator

0°C from initial temperature of 26°C was found to be 26 h 50 min with a total electrical energy consumption of 4.43 kWh. The profile for water temperature, compressor inlet and outlet temperatures and evaporator temperature is shown in Figure 7. The total cooling generation was estimated 19.5 MJ and cooling generation rate was estimated to be 0.7 MJ/h. The system's coefficient of performance (COP) was approximately 1.18. When tested under both winter and summer conditions, the system successfully maintained the chamber temperature within the range of 2-8°C.



Figure 8: Up-scaled solar DC refrigerator with thermal backup

Additionally, an up-scaled solar refrigerator integrated with thermal backup was developed, as illustrated in Figure 8. The refrigerator body was modified to include thermal backup provisions on all four sides and the bottom. A 100 L stainless steel (SS) storage chamber was integrated within the refrigerator body. Testing of the system with thermal back-up is in progress.

1.4 Nano-materials applications in solar Nanofluid using waste engine oil



Figure 9: Vacuum filtration unit

Waste engine oil (WEO) samples were initially filtered through cotton cloth to eliminate large impurities and visible contaminants. Before vacuum filtration, the samples were mixed with hexane to reduce viscosity. The diluted oil was then filtered using a glass fiber filter and a vacuum pump arrangement, as shown in Figure 9. The filtration process was

performed twice: first with a 1.0 μm pore size filter and then with a 0.2 μm pore size filter. Nanofluids were prepared using filtrate of waste engine oil (FWEO) as a nanoparticle source at varying concentrations (0.15% to 2% v/v), with paraffin oil as the base fluid. During the nanofluid preparation mechanical mixing time was set to 15 min at 500 RPM and sonication time was set 10 min at 20 kHz frequency. Visual inspection of the nanofluid reveals that the particles did not settle down even after two months of storage time as can be seen from Figure 10.

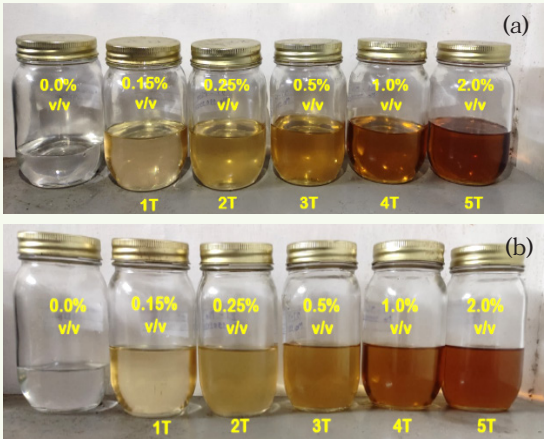


Figure 10: Nanofluid samples (a) right after preparation and (b) after two months of storage

This indicates excellent stability and dispersion of the nanoparticles in the fluid. UV-Vis spectroscopy was carried out for the prepared samples to check the absorbance. Figure 11 (a) illustrates the absorbance profile of distinct nanofluid samples at wavelengths ranging from 220 nm to 750 nm. Further confirmation of the size and chemical composition of the nanoparticles will be carried out using SEM/TEM and EDX/XRF. Particle size analysis of the prepared nanofluid samples were conducted using a Malvern S90 particle size analyzer to determine the size distribution of nanoparticles dispersed in the paraffin oil base fluid. The hydrodynamic size of the nanoparticles exhibited variation within the range of 113.4 nm to 141.9 nm across different samples. At the same time, the poly dispersive index demonstrated variability within the range of 0.32 to 0.64 as can be seen from the plot in Figure 11 (b).

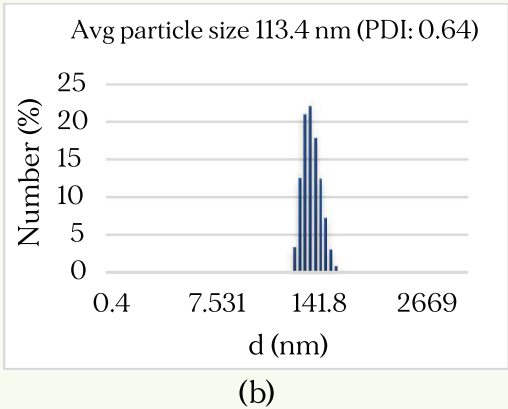
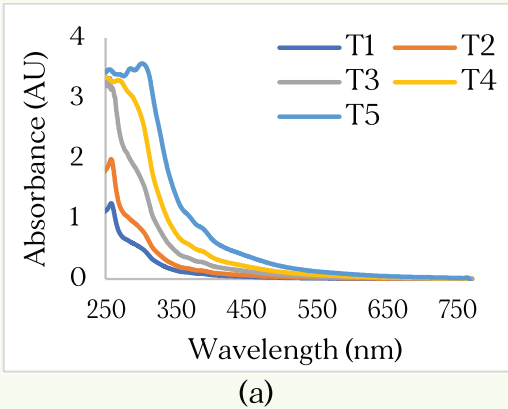


Figure 11: (a) UV-Vis absorbance spectrum for prepared nanofluid (b) particle size distribution

1.5 Solar based essential oil extraction

The proof-of-concept experiments were conducted on hydro distillation and steam distillation method for extraction of essential oil from eucalyptus leaves. The hydro-distillation was carried out on 500 g of leaves which yielded 2 g of eucalyptus oil in four hours. The steam distillation was carried on 2 kg of eucalyptus leaves that yielded 10 gm of essential oil in four hours. The extracted oil is shown in Figure 12 (right). Energy consumed in steam distillation method was 4.4 kWh for processing of 2 kg eucalyptus leaves. Essential oil yield was calculated as 0.4% and 0.5% for hydro distillation and steam distillation methods, respectively, which is significantly higher than 0.19% as reported in literature.

Based on the results of lab scale experiments, sizing of green steam-based extraction system for high value aromatic/medicinal products was done. Green steam-based extraction system mainly consists of parabolic trough collector, heat exchanger (boiler) extraction unit (distillery), and condenser. Parabolic trough collector of 30 m² was estimated to be sufficient for processing of 10 kg aromatic/ medicinal biomass per batch. Extraction unit of 0.3 m diameter and 1 m height was estimated to be sufficient to process 20 kg aromatic/medicinal biomass per day. Based on the size fabrication work of parabolic trough, extraction unit, and condenser was completed.

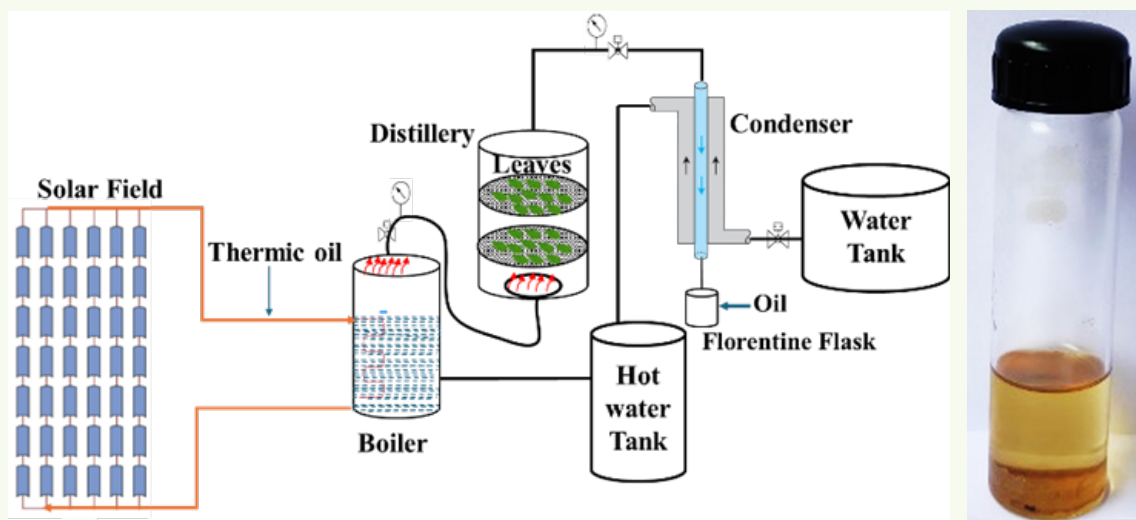


Figure 12: Schematic of solar-thermal based steam distillation system (left); extracted essential oil from eucalyptus leaves (right)

2.1 Sorbitol production from agro-waste

Potential of agro-waste residues such as rice straw and banana fiber as feedstock for sorbitol production was demonstrated (Figure 13). A combination of ionic liquids (ILs), natural deep eutectic solvent (NADES) and strong acid (HCl) was used for pretreatment of rice straw and banana fiber to enhance the recovery of cellulose. ILs and NADES individually exhibited cellulose recovery up to 77% and 87%, respectively. Addition of HCl to IL and NADES combination enhanced the cellulose recovery to 93% under optimized conditions. The cellulose was converted into MCC by a series of pulverization, bleaching, acid hydrolysis and de-polymerization steps.

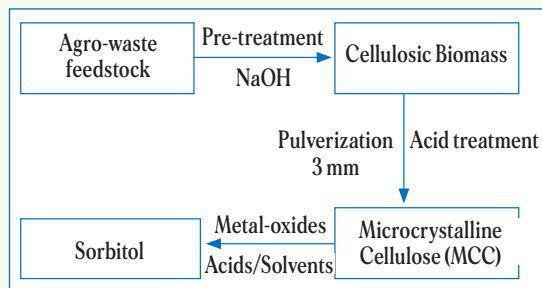


Figure 13: Schematic illustration for sorbitol production from agro-waste process

The obtained MCC was converted to sorbitol through one-pot procedure *via* catalytic hydrolysis and hydrogenation. Glacial acetic acid (GAA) and various metal oxides were tested for conversion of MCC to sorbitol (Table 3). Sorbitol from rice straw-based MCC produced sorbitol in the range of 126 mg/g to 158 mg/g with a maximum yield of 15.8% with stannous oxide and hydrochloric acid. Banana fiber based MCC produced sorbitol in the range of 139 to 180 mg/g and maximum yield of 18.0% was achieved with magnesium oxide and glacial acetic acid (GAA).

Table 3: Sorbitol production from various metal oxides and catalysts in GAA acid

Catalysts	Sorbitol from Rice straw (mg/g)	Sorbitol from Banana Fiber (mg/g)
Magnesium oxide	126.1	180.1
Stannous oxide	158.0	172.8
Vanadium pentoxide	154.5	139.7
Bismuth oxide	151.8	150.5
Ferrous oxide	151.4	139.3
Cadmium oxide	134.3	174.9
Lead dioxide	126.7	167.1
Yttrium oxide	148.1	163.1

2.2 Carbon sequestration from microalgae

The ability of microalgae to absorb carbon dioxide (CO₂) from atmosphere adds to their attractiveness for carbon sequestration in industrial processes. A process for biological sequestration of CO₂ from flue gas for algal cultivation and natural synthesis of polyunsaturated fatty acids (PUFA) was developed. The higher the intake of CO₂ by algae, higher will be its biomass leading to higher polyunsaturated fatty acids (PUFA) content in the lipids.

This technology can absorb CO₂ as a carbon source for the microalgae growth. Optimization studies with varying CO₂ concentrations from flue gases derived from firewood and coal and measurement of CO₂ sequestration potential across different cultivation systems was performed. A flue gas generation system was developed using a biomass burner with firewood and coal as solid fuels. The flue gases were fed into the photo-bioreactor using vacuum pump (Figure 14). The composition of the gas was analyzed using flue gas analyzer integrated with the test



Figure 14: Microalgae experiments for flue gas sequestration

set up. Initial experiments were performed with 2%, 4%, and 6% CO₂ concentrations from both firewood and coal as a source for flue gas. The PUFA content was characterized by extracting lipid from the microalgae. In both cases i.e. firewood and coal, the major fatty acid precursors i.e. palmitic (C16:0) and stearic acid (C18:0) were observed in all three concentrations of CO₂. Further, ω-6 and ω-3 PUFA namely linoleic (C18:2) and α-linolenic acid (C18:3) were detected

in the fatty acid profile. Eicosapentaenoic acid (C20:5), docosahexanoic acid (C22:6) and the precursor arachidonic acid (C20:4) were also observed in the lipids of the microalgae. The biomass, total lipid varying from 2.10 to 2.82 g/L of dry cell weight, and PUFA content are listed in Table 4. PUFA yield was 36 to 44% of the total lipid content in the microalgae. The CO₂ sequestration was 0.41 to 0.46 g/L/day with 6% CO₂ in the flue gas.

Table 4: Total lipid and PUFA content in oil extracted from microalgae

Flue gas concentration (CO ₂ %)	Microalgae weight (g/L)	Total lipid content (g /100 g)	Lipid PUFA (%)
Flue gas from firewood			
2	2.42 ± 0.18	16.2 ± 1.3	38.2 ± 3.3
4	2.68 ± 0.24	16.7 ± 1.2	42.7 ± 3.5
6	2.82 ± 0.23	18.0 ± 1.4	44.1 ± 3.6
Flue gas from coal			
2	2.10 ± 0.17	14.1 ± 1.2	36.0 ± 2.8
4	2.45 ± 0.20	15.9 ± 1.4	40.2 ± 3.4
6	2.61 ± 0.22	16.8 ± 1.5	41.6 ± 3.3

2.3 Anti-microbial composite films from agri-residues

This work developed a biodegradable antimicrobial packaging films from agricultural residue. A composite film of MCC with silver nanoparticle (AgNP) in polyvinyl alcohol (PVA) matrix was developed and optimized to obtain high anti-microbial activity. The optimization studies for cellulose extraction from rice straw biomass was performed using Box-Behnken Design of Response Surface Methodology (RSM). The experiments were conducted under optimized conditions that resulted in 74.6% cellulose, 12.7% hemicellulose and 2.5% lignin. Rice straw cellulose was bleached using NaClO_2 and HCl followed by de-polymerization of cellulose to produce MCC at 50°C . The particle size of MCC was found in the range of 80-250 μm . The removal of lignin during depolymerization was confirmed using FTIR spectroscopy which clearly showed the absence of lignin peak at 1510 cm^{-1} . The MCC was impregnated with silver nanoparticle solution at different concentrations ranging from 1 to 5 milli Mole and composite films were prepared with 5% polyvinyl alcohol (PVA). MCC bio-composite film was investigated for anti-microbial activity against six different microbial strains

that clearly showed zone of inhibition in the range of 3 to 20 mm for all strains indicating good antimicrobial activity of the developed composite films from agro-residues. The MCC impregnated with AgNPs, synthesized composite film and antimicrobial activity is shown in Figure 15. Similar experiments were also carried out for banana fibers that also yielded promising antimicrobial activity.

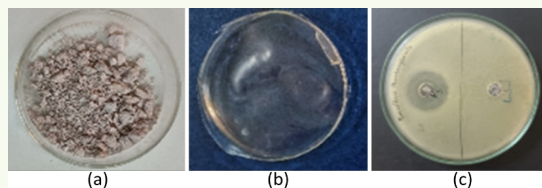


Figure 15: (a) AgNPs impregnated MCC powder (b) MCC based composite films using PVA (c) Antimicrobial activity of AgNP based MCC composite film

2.4 Cellulose and lignin based nanocomposites from agri-waste for biodegradable packaging

Studies on development of NADES combinations were performed using choline chloride as hydrogen bond acceptor (HBA) and hydrogen bond donors (HBD) such as lactic acid, malic acid, urea and glycerol. Lactic acid and choline chloride (9:1) gave maximum lignin and cellulose extraction

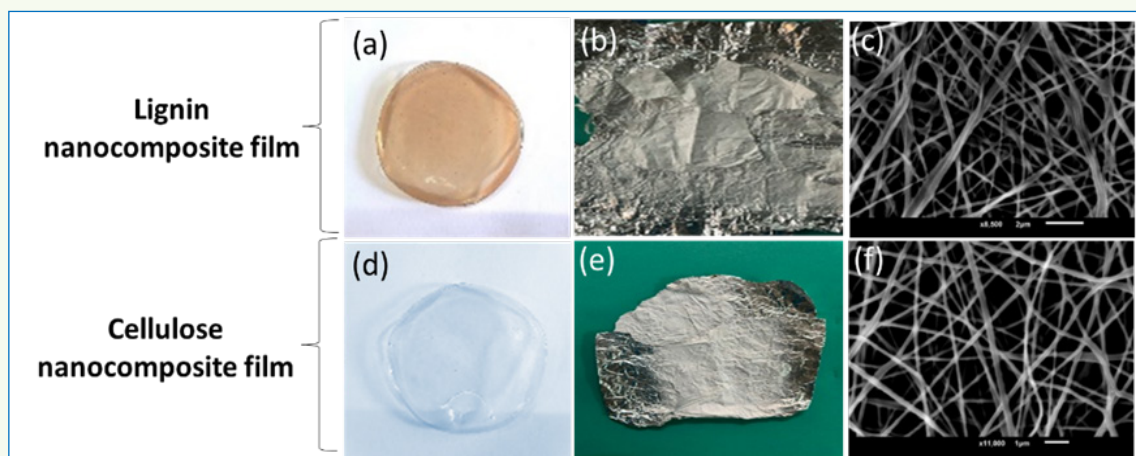


Figure 16: Lignin and cellulose nanocomposite films (a) lignin film prepared by solvent casting method, (b) lignin film by electrospinning method, (c) SEM image of lignin film, (d) cellulose film by solvent casting method, (e) cellulose film by electrospinning method, (f) SEM image of cellulose film.

efficiency compared to other solvents. Cellulose nanocrystals (CNC) from rice straw were optimized for temperature, bleaching time, acid hydrolysis time and sonication time. The FTIR measurements for cellulose showed the absorption bands at 3400 cm^{-1} & 2800 cm^{-1} which were attributed to the OH & CH stretching bonds of the compound CNC. The lignin nanoparticles (LNP) samples showed peaks at $1511\text{--}1508\text{ cm}^{-1}$ that was attributed to the characteristic vibrations of aromatic structures of lignin molecules. The UV-Vis spectroscopy yielded the peak absorption (λ_{max}) at 265 nm and 280 nm that corresponded to the standard values of cellulose and lignin, respectively. Further, a 5% blending of polyvinyl alcohol (PVA) for preparation of nanocomposite films were also carried out. Two different approaches i.e. solvent casting method and electrospinning method were used to prepare the nanocomposite films. Figure 16 (a) shows the lignin film prepared by solvent casting method, while the film prepared by electrospinning method is shown in Figure 16 (b). The cellulose film prepared by the solvent casting method and electrospinning method are shown in Figure 16 (d) and Figure 16 (e). The SEM images of the lignin and cellulose electrospun film are shown in Figure 16 (c) and Figure 16 (f), respectively. Dense network of thick fibers could be seen for lignin nanocomposites compared to that of the cellulose nanocomposite fibers. A visual inspection of the film showed that both the lignin and cellulose films prepared by solvent casting method were more uniform and transparent compared to the films that were prepared by the electrospinning method. Mechanical tearing test performed by hand also indicated better mechanical strength of the films prepared by the solvent casting

method compared to that of electrospinning method. Further, measurements to evaluate the mechanical strength and biodegradability of the prepared films are in progress.

2.5 Synthesis of lubricant from microalgae

To achieve cascading valorization of renewable carbon, a multi-disciplinary approach is required, such as biomass to fuels, bio-refining, and carbon capture utilization and sequestration (CCUS). The use of microalgae for biological wastewater treatment provides a dual advantage: it removes both organic and inorganic pollutants from wastewater and generates sustainable biomass for biofuel production. This study utilized dairy wastewater to grow microalgae for oil extraction and subsequent chemical modification to produce biolubricants. Microalgae strains sourced from dairy facility waters, identified as *Poteriospumella* sp., *Nephrocytium* sp., and *Tetradasmus* sp. through 18S sequencing, yielded biomass quantities of 2.12 g/L for *Poteriospumella* sp. and *Tetradasmus* sp., and 2.06 g/L for *Nephrocytium* sp. *Nephrocytium* sp. also showed the highest lipid content at 46.6%, compared to 40% for *Poteriospumella* sp. and 35% for *Tetradasmus* sp. (Figure 17). A scale-up experiment in fed-batch mode using dairy wastewater in an open raceway pond has begun, with initial batches producing algal biomass with dry weights of 2.1 g/L and 2.3 g/L in subsequent batches. To cut production costs, lipid extraction was conducted directly from wet algal biomass, bypassing the drying process. This method yielded 15% neutral lipids from wet algae and 10% from dried algae. The biolubricant synthesis process, optimized with vegetable oils, is now being adapted for microalgal oil to achieve the highest possible yield.

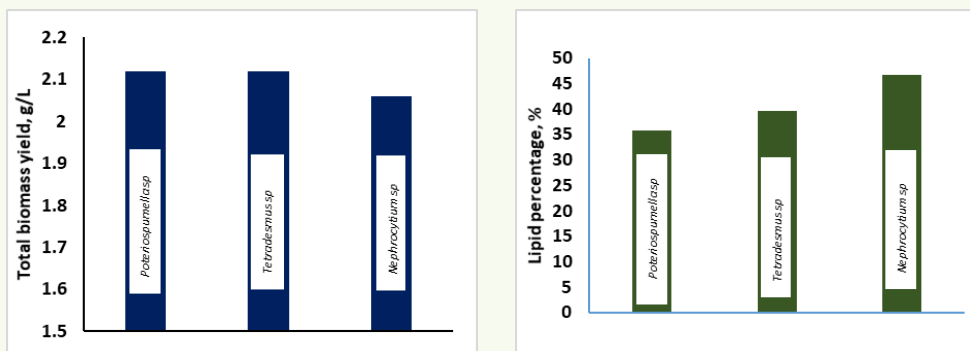


Figure 17: Biomass and lipid profile of newly isolated strains

2.6 Encapsulation of the microbial consortia

The SPRERITECH Compost Consortia consists of a specific blend of four bacterial and six fungal strains that are designed to reduce the decomposition of agricultural residue from 45 days to 21-days. The encapsulation process begins by culturing each strain in optimized growth media to ensure maximum cell proliferation. After the strains have grown optimally, the microbial biomass is harvested via centrifugation. This biomass is then subjected to lyophilization, an essential freeze-drying process that removes moisture while maintaining cellular integrity. During lyophilization, the microbial cultures are frozen, and the pressure is lowered to allow ice to sublime, turning the microorganisms into a stable dry powder ideal for storage and transport. In the final step, the lyophilized microbial powder is encapsulated using capsule fillers (Figure 18). Each capsule contains two strains of microbes, resulting in five capsules in total; two yellow capsules with the four bacterial strains and three green

capsules with the six fungal strains. This color-coding facilitates easy identification and application. The encapsulation process effectively produced stable capsules containing the SPRERITECH Compost Consortia. Subsequent tests confirmed that the lyophilized powder retained microbial viability, ensuring effective microbial activity during use. These encapsulated strains are suitable for storage and transportation of fixed quantity of viable cells for inoculum preparation.

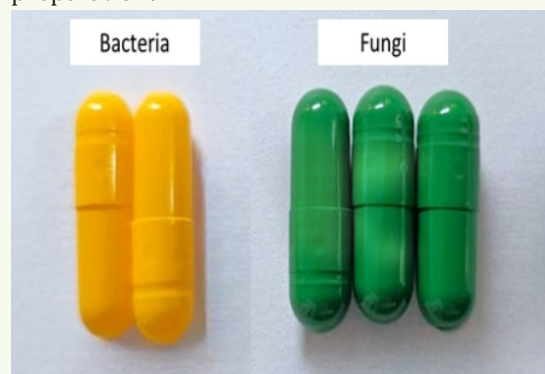


Figure 18: Capsulated SPRERITECH bacterial and fungal strains

3.1 Gasification

Fluidized bed gasification system for Poha-making industry

A poha-making industry, M/s Krishna Agro Food, Nava Rabadiya located in Mahisagar, Gujarat have signed an MoU with SPRERI for installation of a fluidized bed gasification system. The developed system (Figure 19) will replace their conventional combustion system for roaster used in poha making.



Figure 19: Fluidized bed gasification system installed in Poha making industry

The company's effort towards sustainability aims to achieve better thermal efficiency to reduce the land requirement. Preliminary thermal data of the plant based on their current practice has already been collected. Presently, the company is using torrefied residue of

the rice husk as a fuel to meet their thermal energy requirement. Their fuel consumption for roasting one tonne per hour of paddy is 110 kg/h with an overall thermal efficiency of approximately 12%. Considering their thermal requirement, fluidized bed gasification system having capacity of 100 kg/h (system efficiency 70%) has been finalized for system evaluation at site.

Green steam generation using fluidized bed gasification system

Green steam generation is one of the emerging areas of research towards decarbonization. Renewable energy interventions are key towards green steam generation where biomass based technologies play a crucial role. A comprehensive assessment was carried out on a commercial fuel flexible 100 L/h capacity steam generation system. The procured system was fuel flexible where different fuel types can be used. The system performance was evaluated on different fuel types *viz.* solid, liquid and gaseous. For 75 ± 5 kg/h steam generation at $165 \pm 3^\circ\text{C}$ and 5 ± 0.5 bar output pressure; the charcoal, wood blocks, LPG, and diesel showed fuel consumption rate of 16.6 kg/h, 26.1 kg/h, 8.5 kg/h, and 9.6 L/h, respectively. The lowest steam generation cost was observed with wood blocks at Rs. 1.5 per kg. In comparison, the costs for charcoal, LPG,

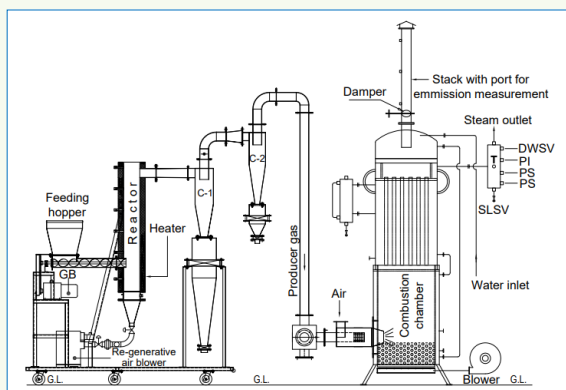


Figure 20: Schematic diagram of steam generation system integrated with fluidized bed gasification system

and diesel were Rs. 3.9 per kg, Rs. 10.1 per kg, and Rs. 11.1 per kg, respectively.

Later, the steam generation system was retrofitted with in-house developed burner to utilize producer gas generated from fluidized bed gasification system. The schematic of the system is shown in Figure 20. The integrated system was evaluated for steam generation using sawdust as feedstock for gasification. For 94 kg/h steam generation at 5 ± 0.5 bar pressure and $165 \pm 3^\circ\text{C}$ temperature requires fuel consumption of 30.6 kg/h saw dust. It was estimated that for the annual operation of 1-TPH steam generation at 5 ± 0.5 bar with biomass has a potential to reduce the annual fuel cost by Rs. 46 lakhs with net CO_2 emission reduction of 169 tonnes per year.

3.2. Pyrolysis

Biofuels from banana tree wastes

Banana is India's second-largest fruit crop contributing to approximately 29% of total global production. Maharashtra, Tamil Nadu, Gujarat, and Andhra Pradesh are major cultivating states of India. In the year 2020-21, India produced 30.57 million tonnes of banana generating significant biomass waste. The banana cultivation yields 30 tonnes/hectare of fruit generating approximately 1000 tonnes of biomass waste that comprises 60% residue from the stem alone.

A feasibility study was conducted to utilize banana waste for bio-oil production through the pyrolysis process. Experiments were conducted to optimize the pyrolysis temperature and residence time for maximum bio-oil recovery. The optimal temperature was determined to be $475 \pm 5^\circ\text{C}$ with a total processing time of 2 hours in batch operation, resulting in bio-oil and biochar yields of 24.1% and 37.5%, respectively. The continuous fast oxidative pyrolysis of banana waste was carried out in a 10 kg/h fluidized bed pyrolysis system developed by SPRERI as shown in

Figure 21. The calorific value of the bio-oil was found to be 27.1 MJ/kg. The calorific value can be further enhanced by removing the moisture (15%) and solid contents (7%) that were present in bio oil.



Figure 21: Fluidized bed oxidative fast pyrolysis system for utilization of banana tree waste

The comprehensive assessment of the biochar obtained as a by product during the extraction of bio-oil from banana waste. The ash content and volatile matter in the biochar was found to be 23% and 33%, respectively while the density and calorific values were found to be 131 kg/m^3 and 21 MJ/kg, respectively. The results showed significant value addition when raw banana waste was converted to biochar. The calorific value of the obtained biochar was found to be 27.8% higher compared to the raw banana waste with additional benefits of possessing less volatile content and high fixed carbon content. The fuel properties of the obtained biochar were found comparable to the properties of Indian coal (Table 5).

The total energy required for processing 100 kg of banana feed during pyrolysis was found to be approximately 120 kWh. The energy equivalent of the pyrolysis products obtained was found to be 370 kWh. The bio-economics analysis suggested that the conversion of 100 tonnes of waste banana biomass into bio-oil and biochar would save 170 tonnes of CO_2 per year as compared to coal. Further experiments of banana tree waste conversion through the pyrolysis process in a pilot scale continuous slow pyrolysis system and utilization of the bio-oil in

Table 5: Properties of biochar prepared and its comparison with Indian coal

	Proximate analysis (wt.%)				Bulk density (kg/m ³)	Calorific value (MJ/kg)
	Moisture content	Volatile Matter	Ash content	Fixed carbon		
Raw banana waste	12.2	66.7	15.1	6.0	154	16.2
Biochar	2.1	33.2	23.8	40.9	131	20.7
Indian coal	7-20	10-45	20-35	35-50	600	18-25

the developed bio-oil burner are under progress.

Carbon capture using biomass ash

Mitigation of CO₂ emissions is a critical area of present research. Replacing coal with biomass is one of the renewable ways of addressing carbon emissions arising from the burning of fossil fuels. Direct combustion of biomass is a dominant conversion process for the production of bioenergy. However, this is estimated to produce 476 million tonnes of ash per year globally. Re-use of the produced ash to capture CO₂ from the atmosphere offers a promising application that needs to be comprehensively investigated.

An experimental bench-scale reactor was designed for CO₂ adsorption with ash storage capacity of 100 g as shown in Figure 22. To maintain the temperature of the reactor, a ceramic based heater was used. The ash was generated using different biomass namely the rice straw, sawdust, and groundnut shell. The ash yield obtained from the bench-scale reactor was 15.8%, 7.2%, and 10.3%, respectively. The elemental composition of the ash was characterized using WD-XRF analysis. High percentage of oxides of sodium (12.9%), potassium (13.3%), calcium (17.8%), and magnesium (6.5%) were found in these ash samples. These oxides react with CO₂ at 200°C to form stable carbonates. Based on the metal oxide composition of ash, an estimation was carried out to assess the CO₂ adsorption capacity of the ash. The calculations indicated that depending on the metal oxide composition of the ash, a total of 1.4 L to 1.6 L of CO₂ can be adsorbed by one kilogram of the biomass ash, which is quite promising. Presently, optimization of the

process parameters i.e., pressure, gas retention time and temperature followed by feasibility trial is in progress.

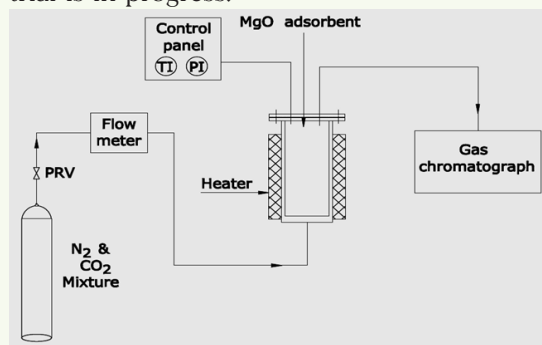


Figure 22: Schematic of the biomass ash based carbon capture setup

3.4 Life cycle assessment of rice straw torrefaction process

Rice straw, a by product of rice production, has significant potential as a renewable energy source. Torrefaction, a thermal pretreatment process, converts rice straw into a more energy dense, hydrophobic, and easier-to-grind solid biofuel. This report presents a Life Cycle Assessment (LCA) of rice straw torrefaction, focusing on the environmental impacts from the harvesting site pickup to the conversion into torrefied biomass. The system boundary and flow for torrefaction process of rice straw is shown in figure 23. The LCA framework is shown in Figure 24. The mass and energy balance system is shown in Figure 25. The functional unit is defined as per the system boundaries are set from the collection of rice straw to the formation of the torrefied product. The impact assessment was conducted based on 100 kg/day processing of rice straw over categories such as Global Warming Potential (GWP), Acidification Potential (AP),

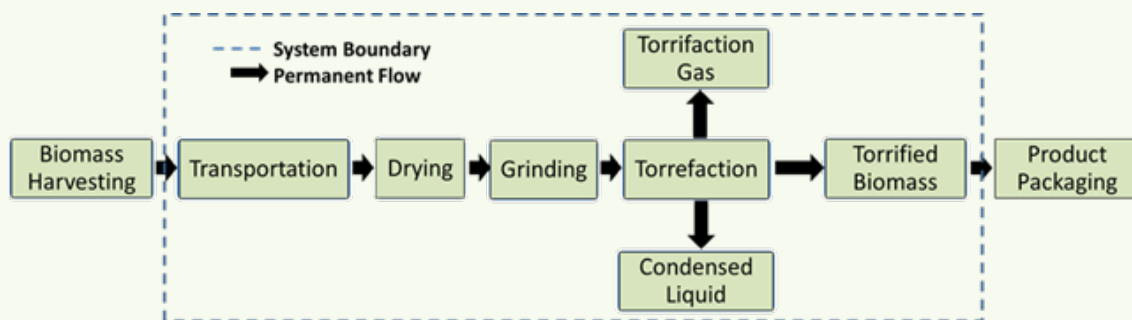


Figure 23: System boundary and permanent flow for torrefaction process of biomass



Figure 24: A typical LCA framework (ISO:2006)

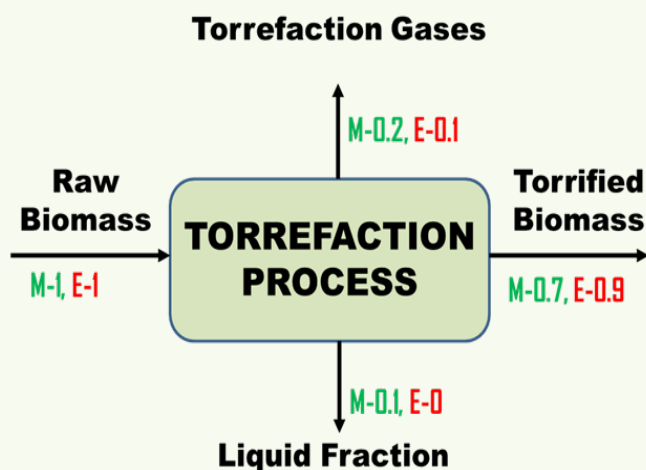


Figure 25: Mass and energy balance for torrefaction process

Eutrophication Potential (EP), Human Toxicity Potential (HTP), Ecotoxicity Potential (ETP), and Resource Depletion.

Life Cycle Impact Assessment (LCIA) was performed using SimaPro software, employing impact assessment methods such as TRACI and CML. The major impact during transportation was observed in AP due to emissions of NO_x from diesel engines. During preprocessing (grinding), the major effects were observed on GWP due to energy intensive operations and on AP due to emissions from machinery and energy use. The EP was minimally affected by this process. The torrefaction process contributed

the most to the overall impact compared to transportation and preprocessing steps. During torrefaction, GWP showed the highest impact due to energy use and emissions from heating and electricity consumption, while AP reported a high impact due to the generation of acidic liquid phases. EP was minimally affected by the process, while emissions of CO and other pollutants affecting human health contributed to HTP. ETP was also highly affected by the release of pollutants impacting ecosystems. Lastly, the significant use of energy resources also impacted the most during the torrefaction process. To conclude, the torrefaction process stage

has the highest environmental impacts, particularly in terms of GWP, AP, and resource depletion, due to significant energy consumption and emissions. Preprocessing also contributes significantly to the overall impacts.

Table 6: Impact analysis of 100 kg/day torrefaction process unit for rice straw

Impact Areas	Classification	Units	Amount
Global Warming Potential	Overall	kg CO ₂ eq.	10.000
	Ozone layer depletion	kg CFC11 eq.	2.43 × 10 ⁻⁶
Acidification Potential	---	Kg SO ₂ eq.	0.0317
Eutrophication Potential	---	Kg N eq.	0.0005
		Kg P eq.	0.0090
Human Toxicity Potential	Non-carcinogenic	kg 1,4 DCB	14.600
	Carcinogenic	kg 1,4 DCB	1.2600
Ecotoxicity Potential	Marine	kg 1,4 DCB	0.6550
	Freshwater	kg 1,4 DCB	0.4700
	Terrestrial	kg 1,4 DCB	47.300
Resource Depletion	Mineral Resource	kg Cu eq.	0.0100
	Fossil Resource	kg Oil eq.	2.6500

Hydrogen Generation

4.1 Bio-hydrogen from agricultural residue

Bio-hydrogen through dark fermentation routes is being carried out as a part of waste to energy and circular economy initiative. Pure strains of hydrogen producing bacteria namely, *Enterobacter cloacae* (SPA4), *Staphylococcus epidermis* (SPS3) and *Shigella flexneri* (SPD1) were isolated from anaerobic sludge (SPA), soil (SPS), and rice straw dump (SPD). Experiments were conducted in YMG media comprising of 1% glucose and 10% inoculum (v/v). The reactors (Figure 26) were incubated at 37°C for 72 hours under anaerobic conditions. Hydrogen produced by SPA4, SPS3 and SPD1 was found to be 58.7%, 59.3% and 56.2%, respectively as shown in Table 7. Later, NADES pretreated enzymatic hydrolysate of rice straw cellulosic fraction was used as renewable source of sugars for

bio-hydrogen production. Presently, lab scale experiments on 5 L reactors and fermenters are ongoing. Upscaling of the existing reactor system by 8-10 times are underway. In addition, existing 30 L pretreatment system for agri-residue to sugar conversion will be used for synthesis of reducing sugars as feedstock for bio-hydrogen production.



Figure 26: Experimental setup for Biohydrogen production

Table 7: Hydrogen production and yield from newly isolated bacterial strains

Code	Strain name	Total gas (mL)	Hydrogen (%)	Hydrogen (mL)	Hydrogen yield (mol/mol hexose)
SPA4	<i>Enterobacter cloacae</i>	1430.0	58.7	840.0	2.7
SPS3	<i>Staphylococcus epidermis</i>	910.0	59.3	540.0	1.7
SPD1	<i>Shigella flexneri</i>	1810.0	56.2	1000.0	3.2

4.2 Bio-hydrogen production from agro-residues via thermo-chemical conversion route

SPRERI has developed a Water Gas Shift Reactor (WGSR) for converting the syngas produced from biomass using biomass gasification technology. The developed WGSR system is being optimized with different catalysts and carbon-to-steam ratio (CSR) using an in-house developed catalyst. The syngas produced from the gasification system pass through a series of filters (Gas cleaning train) where the gas is purified from impurities such as tar or particulate matter.

The clean gas is then supplied to the WGSR for further processing. The syngas produced from steam gasification undergo the water-gas shift reaction (WGSR) in a two-stage reactor system. The two-stage Water-Gas Shift Reaction (WGSR) is a process in which the conversion of carbon monoxide (CO) to carbon dioxide (CO₂) and hydrogen gas (H₂) occurs in two successive reactor stages, each operating under different temperature and catalyst conditions allowing better control over reaction kinetics and the overall efficiency. The first stage typically operates at higher temperatures (350°C to 500°C)

and utilizes a high-temperature catalyst. At these elevated temperatures, the reaction kinetics are faster, and the catalyst exhibits high activity for converting CO to CO₂ and H₂. The second stage operates at lower temperatures (200°C to 300°C) and uses a low-temperature catalyst. Here, the reaction kinetics are slower compared to the first stage. The low-temperature catalyst is chosen for its activity in restricting the reverse reaction that converts CO₂ back to CO.

Finally, the hydrogen-rich syngas obtained from the two stage water gas shift reactor undergoes hydrogen separation via adsorption using a combination of amines for CO₂ adsorption, thereby producing high-purity hydrogen gas. An alternative system for generating pure CO₂ during desorption is also designed. The project has progressed to the retrofitting of gasifier, steam generator, water gas shift reactor and CO₂ absorbing column as shown in Figure 27. Further study is in progress.

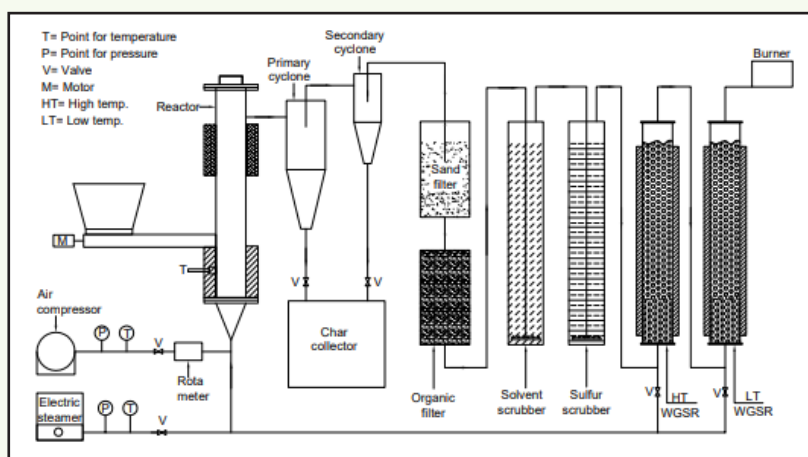


Figure 27: Concept diagram of hydrogen production by Water Gas Shift Reaction

Technology Transfer and Extension Division

5.1 Demonstration, Training and Awareness Creation Program

5.1.1 Demonstration of SPRERI technologies

Demonstration of biomass cook stoves and micro solar dome in 21 villages of Gujarat

SPRERI conducted a demonstration and awareness program in selected villages across four districts of Gujarat: Anand, Kheda, Vadodara and Panchmal. The program aimed to educate rural communities about the negative health and environmental effects associated with traditional C-type chullahs used for cooking. As shown

in Figure 28, there were 32 demonstrations conducted across 21 villages, engaging more than 1500 attendees. Additionally, it focused on introducing the use of micro solar domes for lighting in areas where grid supply is unreliable or unavailable. Live demonstrations were held for both micro solar domes and SPRERI developed cookstove, highlighting how these innovative renewable energy solutions can reduce pollution, save time, and lower fuel costs (Figure 29). The program received enthusiastic participation from villagers.

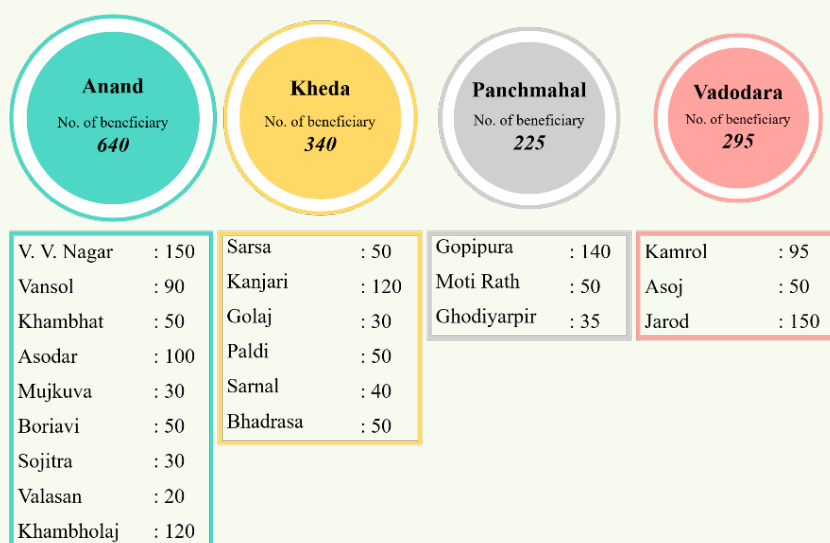


Figure 28: Data showing districts covered, number of beneficiaries, villages covered and number of beneficiaries in each village during Demonstrations



Figure 29: Renewable energy technology demonstration at Kanjari



Figure 30: SPRERITECH Cookstove demonstration at Mothirath village

Demonstration in the program organized by Foundation for Ecological Security

SPRERI participated in the event organised by Foundation for Ecological Security (FES), Anand, for rural development program in Mothirath village, situated in Mahisagar district. SPRERI team demonstrated the SPRERITECH cook stove as a sustainable alternative to traditional chullahs used for cooking in rural areas (Figure 30). Approximately 2000 participants attended the event, demonstrating strong interest in adopting SPRERITECH improved biomass cook stoves over their current conventional cooking methods.

5.1.2 Training and awareness programmes
GEDA supported training programmes on Renewable Energy and Energy Conservation

SPRERI organized a training program on Renewable Energy and Energy Conservation with support from Gujarat Energy

Development Agency (GEDA), Government of Gujarat. The objective of this initiative was to raise awareness among citizens, focusing on youth, students, and farmers regarding the significance of renewable energy and energy conservation for enhancing energy security and promoting environmental sustainability. A total of 35 training programs were conducted. Each program consisted of six sessions, the flow of the sessions is given in Figure 31. The experts from nearby universities, certified energy auditors and scientific staff of SPRERI gave the lectures (Figure 32). These sessions were followed by live demonstration of the renewable energy technologies at SPRERI. The scientific staff of SPRERI gave the demonstrations as shown in Figure 33. A dedicated Q&A session was also organized to address the queries of the participants. Finally, the feedback was collected from the participants.

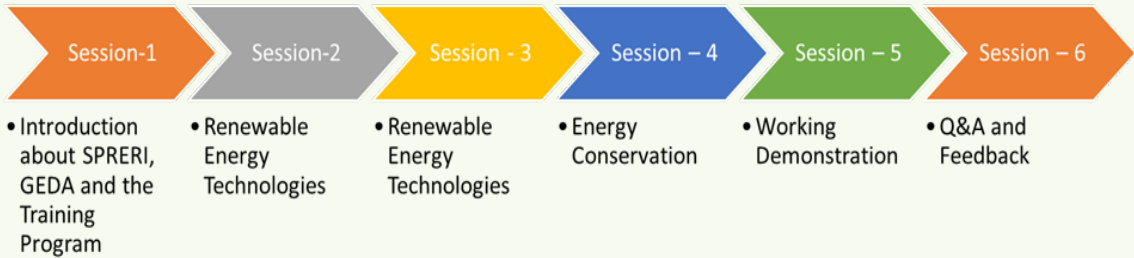


Figure 31: Training programme on Renewable Energy and Energy Conservation



Figure 32: Students attending the expert session



Figure 33: Demonstration of technologies at SPRERI

The program was attended by 1700 participants, consisting of 39% ITI students, 35% engineering students, 10% from polytechnic colleges, 9% farmers, and 7% women from Self-Help Groups (SHGs). The entire program received positive feedback. Participants greatly valued SPRERI's technology demonstrations for providing them with hands-on experience. A common sentiment expressed by participants was their anticipation for long-term programs in the future.

5.1.3 Students' Orientation Programme

In an initiative aimed at connecting theoretical learning with practical applications, students from multiple colleges visited the SPRERI (Figure 34). These students, coming from diverse academic backgrounds, had the opportunity to explore the institute's advanced technologies. The visit not only expanded the students' knowledge but also instilled a commitment to sustainable practices. Besides the Open House event, SPRERI has welcomed over 350 students from various colleges this year.



Figure 34: Interaction with team SPRERI during educational visit

5.2 Field implementation of SPRERI Technologies

5.2.1 Rice straw composting

Management of rice straw is challenging because of short time span available between harvests of paddy straw and sowing of next crop. SPRERI has developed a consortium that shows promise in speeding up the composting of rice straw. The consortia were demonstrated in a farmer's field owned by Vimal Bhai Patel located in Isnav.

The size of the rice straw was reduced to a size of 3 to 5 mm by grinding. Simultaneously, bacterial and fungal inoculums were prepared according to the instructions shown in Figure 36. Separately, dung slurry was prepared by mixing 25 kg of cow dung in 100 L water. The inoculums (1000 L), cowdung dung slurry (100 L), and water were then mixed with the ground straw (Figure 35). Careful mixing ensured an even distribution of microbial cultures and slurry in the rice straw. The heap of straw mixed with slurry and inoculum was formed for its decomposition (Figure 36). The heat generated inside the heap was released every seven days' cycle for three times. Immediately after turning the straw, heap is formed again for further decomposition of straw. The straw remains in the heap for 21 days to get completely decomposed. The decomposed straw was cooled and dried to 35-45% moisture content before its packing and storage.

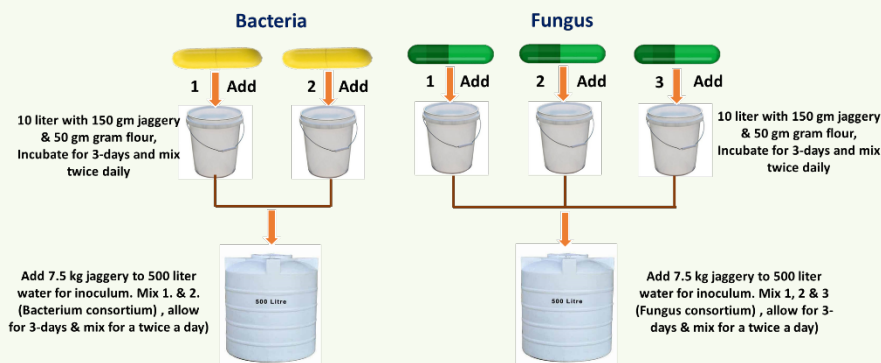


Figure 35: Preparation of inoculum for rice straw composting



Figure 36: Mixing of rice straw and inoculum (left) and rice straw heap (right)

5.2.2 Dissemination of renewable energy technologies to SC community of Gujarat

ICAR has launched a targeted initiative aimed at accelerating socio-economic development among the Scheduled Caste (SC) community through the adoption of renewable energy technologies. As per the 2011 census, the SC population in Gujarat constitutes 6.74% of the total population, amounting to 40,74,447 individuals. The Government of Gujarat recognizes 35 castes under this category. Under the SC Sub Plan (SCSP) of the Government of India, a project was carried out with the support of ICAR-AICRP on EAAI. The project aimed on demonstrating and disseminating SPRERITECH cookstoves and Micro Solar Domes (MSD) to SC community (Figure 37). As shown in Figure 38, over 40 demonstrations were conducted in 29 villages across five districts of Gujarat, attracting

approximately 1800 beneficiaries who attended the awareness and demonstration programs on cookstoves and MSD. Beneficiaries were charged Rs 500/- for cookstoves and Rs 700/- for Micro Solar Domes. Funds collected from this initiative were reinvested for further dissemination of cookstoves within the SC community. Following this approach, a total of 408 cookstoves and 20 micro solar domes were distributed.



Figure 37: Cookstove demonstration to SC community

Anand	Kheda	Vadodara	Gir Somnath	Mahisagar
V.V.Nagar, Bakrol, Ansari, Pandvaniya, Vansol, Khambhat, Anklav, Vanoti, Petlad Dharmaj	Kanjari, Vajevad, Golaj Agarva, Mahemdavad, Bhadrassa, Chaklasi, Nadiyad, Andhaj, Bharathri, Manjipura, Thasra	Kamrol, Jarod	Veraval	Mothirath
Cook stove : 130 MSD : 10	Cook stove : 120 MSD : 10	Cook stove : 74 MSD : Nil	Cook stove : 69 MSD : Nil	Cook stove : 15 MSD : Nil

Figure 38: Districts and villages covered and number of cookstoves and microsolar domes distributed to the SC community

Seventy-six percent of the SC population earns their livelihood as agricultural laborers, while the remainder seeks other labor opportunities nearby. Introducing appropriate technology could significantly improve their quality of life by providing a cleaner cooking environment, reducing firewood consumption, and enhancing lighting facilities in village homes. These technology support have the potential to uplift their current living conditions.

5.2.3 Biomethanation Plant (3.5 TPD capacity)

A 3.5 TPD odorless biogas plant was installed at Karamsad with support from DBT and is operational since August 2022. This plant utilizes kitchen and mandi waste for biogas generation. The biogas produced is used in the canteen of Shri Krishna Charitable Hospital. Since its installation, the plant's performance has been consistently monitored. The average biogas production varied from 80 - 120 cubic meters per tonne of kitchen waste, with methane content consistently ranging from 60-65%. Other key operational parameters observed were the inlet pH ranging from 4.5 - 6.0 and outlet pH ranging from 6.0 -7.0. Several operational challenges were identified, categorized and systematically addressed. They include:

- ☀ Manual segregation of waste continues to be a challenge despite conducting training programs on the importance of waste separation. The lack of knowledge and awareness often results in reluctance to invest time in segregating waste at the source.
- ☀ Transitioning from LPG/PNG to biogas requires a significant shift in mindset and a willingness to adopt new technologies. For many individuals being accustomed to traditional energy sources such as fossil fuels, this change can be daunting and unfamiliar.
- ☀ Consistent feedstock is essential for optimal biogas production. Variations in organic content had impact on biogas production rates. The plant encountered these issues with reduced gas production, indicative of feedstock problems, and these were resolved promptly.
- ☀ The biogas from the production site is transported to the kitchen at a distance of 700 meters. At times, the cracks in pipeline led to gas leakage. The identification of cracks and leakages in the pipeline is a challenge resolved with hit and trials.
- ☀ The shortage of adequately trained personnel for the operation of the plant is also a one of the challenge.

Open House

SPRERI hosted its flagship event, the 15th Open House, on February 28th and 29th, 2024, to showcase and demonstrate the latest technologies in biochemical conversion, thermochemical conversion, and solar energy developed by SPRERI.

The event commenced on the morning of February 28th with an inaugural program (Figure 39) featuring Dr. M.K. Jhala, Director of Research, Anand Agricultural University, Anand, as the Chief Guest, and Ms. Amita Pandya, Senior Project Executive Gujarat Energy Development Agency (GEDA), Gandhinagar as the Guest of Honor. The program was also honored by the presence of Dr. S.G. Patel, Honorary Secretary of Charutar Vidya Mandal, Gujarat. Dr. Anil Kumar Dubey, Director, SPRERI, welcomed the dignitaries and the audience, and introduced the technologies on display.

Dr. Jhala addressed the audience, emphasizing the crucial role of renewable energy in the near future. He commended several of SPRERI's notable technologies and encouraged students to leverage SPRERI's resources for their learning. Ms. Amita Pandya connected with students, highlighting the significance of the Open House and urging

them to take advantage of the opportunity to learn from and interact with SPRERI's scientific staff.



Figure 39: Inauguration programme of Open House

Over the two days, SPRERI demonstrated and explained its technologies through working exhibits presented by its scientists and technical personnel (Figure 40). The event attracted a diverse audience of 2,600 people, including students, professionals, technocrats, entrepreneurs, farmers, women from self-help groups (SHGs), and local residents. Participants included students from ITI and engineering colleges, school students, architecture students, farmers from three Gujarat districts, and women from different SHGs.



Figure 40: Demonstration of technologies during Open House

Consultancy and Testing

7.1 Consultancy Services

The three consultancy services was carried out by the institute

- **Biomass availability assessment for the western region**

The objective of this study was to evaluate the availability of biomass briquettes and pellets within a 300 km radius from Vapi. The goal was to plan the availability of 200 metric tons of agro-residue pellets and briquettes. The study covered parts of Gujarat (28 districts), Maharashtra (16 districts), Madhya Pradesh (seven districts), Rajasthan (two districts), and two Union Territories. The reports were prepared and submitted.

- **Down-draft gasification technology for fertilizer industry**

Under this project, an industrial-scale down-draft gasification system having capacity of 550 kg/h was designed on wood based fuel for a fertilizer industry. The fabrication of system is in progress.

- **Torrefaction and palletization study of selected biomass**

Objective of the study was to carry out the production of torrefied agro residues

for thermal applications with detailed characterization and economic analysis. In this study, process parameters were carried using a batch-scale system; whereas for the continuous production, a pilot scale system having capacity of 20 kg/h was used. Further, the produced materials were densified in the form of 6 mm diameter pellets using a pilot-scale pelletizing machine.

7.2 Testing services

- The Solar powered cold storage of 5 MT capacity was tested for M/s CHDK Technology Center, Pune as per the MNRE guidelines.
- The Solar Biomass Hybrid Dryer of gross area 6.7 m² was tested for The Energy and Resources Institute, Gurgaon as per the MNRE guidelines.
- The performance parameters of the Solar dryer of gross area 0.47 m² was tested for M/s Rudra Solar Energy, Ahmedabad, as per the MNRE guidelines.
- The analysis of producer gas samples (10 nos.) were carried out for M/S Endrick contractor, Anand, Gujarat.

Activities/Events

8.1 Business meet on briquetting of agro residue

The SPRERI organized a one day “Quality Awareness Program for Biomass Briquettes & Pellets Manufacturers” in Navsari, Gujarat with support from the Indian Council of Agricultural Research (ICAR), Government of India, and the Department of Energy and Petroleum, Government of Gujarat (Figure 41).

The event aimed to educate manufacturers

on enhancing quality and understanding economic factors in the production of biomass pellets and briquettes. Over 50 participants, including manufacturers, suppliers, and other eminent persons such as Mr. Kishore Patel, Vice President of the Briquettes and Pellets Association for the South Gujarat Region; Mr. Pankaj Parmar, South Gujarat Representative and Convenor for the Navsari Region; and Dr. Anil Kumar Dubey, Director of SPRERI participated in the event.



Figure 41: Biomass briquettes & pellets quality awareness event at Navsari, Gujarat

The event featured discussions on a range of topics including biomass availability and types, forthcoming regulatory standards, fuel properties, and economical scaling methods for production. Specific issues addressed included increasing production costs and low demand with strategies for mitigating these challenges. Additionally, the dialogue brought attention to difficulties such as the credibility of lab test reports, sampling techniques, and the unregulated supply of raw materials.

A key topic of discussion was the integration of agro-waste into traditional feed materials, which can lower costs and improve calorific values. The event also explored technologies like torrefaction that can enhance product quality and energy content. Additionally, it served as a platform for discussing upcoming standards for pellets and briquettes. The Director of SPRERI and other scientists shared insights on these standards and their potential benefits for the industry.

The convener and South Gujarat representatives expressed their gratitude to the SPRERI team for organizing such an insightful program. This

quality awareness initiative marked a significant advancement for the biomass briquette and pellet industry in South Gujarat, promoting knowledge exchange and encouraging sustainable practices in biofuel production.

8.2 Poster paper competition

SPRERI organized a poster paper competition for college students with an interest in science and renewable energy, centered on the theme “Clean and Green Energy for Sustainable Development.” Invitations were sent to various colleges and academic institutions to submit posters aligned with the theme and preparation guidelines. The response was highly enthusiastic, resulting in a diverse array of innovative and thought-provoking posters (Figure 42). The Poster Presentation event, held on February 28, 2024, featured 25 participants, including SPRERI interns from various colleges, displaying a wide range of novel ideas and research topics. Two external judges evaluated the posters based on set criteria. The prizes were given to the top three poster papers (Figure 43).



Figure 42: Students presenting poster in the poster paper competition



Figure 43: Prize distribution after the poster paper competition

Consolation prizes were also awarded. The event was a great success, showcasing the creativity and commitment of participants towards advancing clean and green energy solutions for sustainable development.

8.3 Technology Exhibition

SPRERI hosted a technology exhibition showcasing innovative advancements aimed at empowering farmers and rural communities through renewable energy solutions (Figure 44). This year's event brought together manufacturers, researchers, and innovators committed to promoting sustainable development. Some manufacturers featured live demonstrations and video presentations. The exhibition emphasized the importance of collaboration and innovation in overcoming

the challenge of delivering renewable energy technologies to users. Looking ahead, maintaining a focus on renewable energy and technologies tailored to rural needs will be crucial for achieving broader socio-economic progress and environmental sustainability.



Figure 44: Exhibition stall during the exhibit at SPRERI campus

New Initiatives

9.1 Library

The SPRERI has recently opened a library dedicated to Renewable Energy Technologies on its campus. The library was inaugurated by SPRERI Director, Dr. Anil Kumar Dubey. The library stocked with a range of interdisciplinary books covering various renewable energy technologies, including solar thermal, solar photovoltaics, thermo-chemical conversions, and bio-conversions. The library has become a popular resource for the institute's research enthusiasts, who benefit from its extensive collection of interdisciplinary literature (Figure 45). It also offers national and regional newspapers to keep employees updated on current events. Non-research staff are encouraged to spend time in the library to develop reading habits and gain knowledge from popular and mass media articles. Plans are underway to subscribe to scientific journals and create e-resources to further support employees and the students.



Figure 45: Inauguration of library by the SPRERI Director (Left); Visitors to the library (Right)

9.2 Hydrogen research laboratory

SPRERI has established a specialized Green Hydrogen production research laboratory dedicated to advancing research across the entire hydrogen value chain, including

production, storage, transportation, and end-use. The lab emphasizes the indigenization of various hydrogen technologies and their components. Its goal is to drive the green energy transition through innovative technologies, foster interdisciplinary collaborations, and offer

training opportunities for young professionals. Currently, the laboratory is equipped with biomass gasification integrated with the water gas shift reactor for hydrogen generation, bio-hydrogen production through dark fermentation (Figure 46).



Figure 46: Hydrogen research laboratory equipped with hydrogen production technologies

9.3 Zero waste campus

To achieve its goal of a clean and green campus, SPRERI has initiated a zero-waste program (Figure 47). This initiative focuses on converting campus-generated waste into useful products. The process began with creating pellets from dried leaves and other biomass waste collected on the campus. The waste is first collected and ground into powder using a hammer mill. After grinding, the powder is fed into a pelleting machine to produce 6 mm pellets. Additionally, the powder is converted into biochar through pyrolysis. Currently, the pellets and biochar are undergoing characterization to assess their properties.



Figure 47: Waste-to-Value process flow

9.4 e-Newsletter

In its ongoing effort to enhance communication and engagement with stakeholders, SPRERI has launched a new quarterly newsletter (Figure 48). This initiative represents a significant advancement in our mission to disseminate information, share progress, and showcase innovations in renewable energy research. The e-newsletter is uploaded on institute website and on social media, LinkedIn



Figure 48: First edition of SPRERI e-Newsletter

Key features of the e-Newsletter:

- Summaries of recent research projects.
- Successful stories, initiatives, demonstration of renewable energy technologies.

- Information on upcoming events by SPRERI.

The quarterly newsletter aims to enhance visibility, foster improved collaboration, expand knowledge among readers, and build a community of like-minded individuals and organizations dedicated to advancing renewable energy solutions.

9.5 Institute seminars

The institute has implemented an initiative that fosters knowledge sharing and keeps the scientific team abreast of the latest advancements in the field of renewable

energy. Each month, one of the scientists delivers a presentation on either a recent development or ongoing research in the field of renewable energy, within the institute. This practice not only highlights the cutting-edge work being conducted by the institute but also promotes an environment of continuous learning. This platform encourages interdisciplinary dialogue, inspire new ideas, and update about the latest scientific trends and breakthroughs. This initiative would enhance our collective expertise and reinforced our commitment to staying at the forefront of scientific discovery.

Memorandum of Understanding

The following MoUs were signed by SPRERI with

- Marwadi University, Rajkot on August 8, 2023 to promote and enhance academic and research interactions.
- Krishna Agro Food, Mahisagar on June

19, 2023 for implementation of Fluidized bed gasification system.

- M/s Advait Infratech Limited on May 22, 2023 for Research and development partnership on hydrogen production

Recognition and Academic Activities

- Bhavin Soni, Urvish Patel, Gaurav Mishra, Geeta Kumari (2023, October 9–12), received the Best Oral Presentation Award at the 4th International Conference on Recent Advances in Bio-Energy Research (ICRABR) at SSS-NIBE, Kapurthala on, *“Development of the fluidized bed gasification system equipped with PLC-based control panel for biomass utilization in thermal industries.”*
- Urvish Patel, Bhavnin Soni, Shardul Amin, Guarav Mishra, Geeta Kumari. (2023, October 9–12), received the Best Oral Presentation Award, at the 4th International Conference on Recent Advances in Bio-Energy Research (ICRABR) at SSS-NIBE, Kapurthala on, *“Production, characterization of char pellets with different organic additives and its demonstration as a fuel in a forced-draft cook stove.”*
- Mr Harshit Kumar Shah and Mr Prakash Damor, B. Tech. students (Mechanical Engineering Branch, BVM college), interns at TCC Division of SPRERI received 2nd position at Project Expo 2023, organised by CVM on, *“Development of a continuous bio-sorbent system for the treatment of bulk milk chiller effluents”*
- Er. Milan Sojitra, appointed as an Evaluator for CVMU Hackathon-2023 organized by A.D. Patel Institute of Technology, March 17-18, 2023
- Er. Asim Kumar Joshi & Dr. Amrita Doshi, appointed as judges for project exhibitions by students on the theme *“Rural Development”* under Mega Event OPEN-R organized by SSIP cell, Research & Innovation Centre, SVIT, Vasad, April 12, 2023

Publications

- Sojitra Milan, Gupta Sachin, Tiwari Arunendra Kumar, Joshi Asim Kumar and Singh Ramkishore (2023). *CFD Simulation of Portable Thermal Storage Device for Solar Cooking System*. In: Doolla, S., Rather, Z.H., Ramadesigan, V. (eds) **Advances in Clean Energy and Sustainability**. ICAER 2022. Green Energy and Technology. Springer, Singapore. pp:529-538, ISBN : 978-981-99-2279-6_46
- Kant Ravi, Kumar Anil and Dubey Mukul Kumar, 2024 “Energetic, Exergetic, Exergoeconomic, and Enviroeconomic Analysis of Solar Dish-Integrated Water Desalination System with Various Nanofluids” **Groundwater for Sustainable development**, 26, 101207.
- Kant Ravi and Kumar Anil, 2023. “Thermo-enviro-economic analysis of Conventional Steam Distillation System for Peppermint Oil extraction” **Journal of Thermal Science and Engineering Progress**, 46, 120246
- Kant Ravi and Kumar Anil, 2023. “Energy-Economic and Exergy-Environment Performance Evaluation of Solar Energy Integrated Essential Oil Extraction System” **Solar Energy**, 265, 112101

Conference, Workshops & Meetings

13.1 International & National Conferences

- Khanpara D., Vekariya M., Chauhan V., Patel U., Soni B., “Utilization of Agro and Industrial Residues for Green Steam Generation: A Step Towards Net Zero Emission”, Poster presentation in the 15th Open House at SPRERI, Anand, Gujarat on February 28, 2024
- Patel K., Amin V., Lad J., Parmar N., Chauhan V., Patel U., Soni B., “Development of a Suitable Burner for Syngas generated from the Pilot-scale Fluidized Bed Gasification System”, Poster presentation in the 15th Open House at SPRERI, Anand, Gujarat on February 28, 2024
- Parekh S., Parmar D., Khanpara D., Singh R. K., Soni B., “Waste to Wealth Conversion: Waste Banana as Raw Material for Energy Production”, Poster presentation in the 15th Open House at SPRERI, Anand, Gujarat on February 28, 2024
- Dedhiya N., Parmar V., Valand N., Soni B., “Demonstration of Groundnut Shell as a Biofuel using Fluidized Bed Gasification System”, Poster presentation in the 15th Open House at SPRERI, Anand, Gujarat on February 28, 2024
- Joshi Asim, “Development and performance evaluation of non-tracking series connected jacketed solar cooker for rural application”, International Conference on Sustainable Energy and Environment (ICSEE 2024), MANIT-Bhopal on February 24, 2024
- Soni Bhavin, “Development of the fluidized bed gasification system equipped with PLC-based control panel for biomass utilization in thermal industries”, 4th International Conference on Recent Advances in Bio-Energy Research (ICRABR) at SSS-NIBE, Kapurthala, October 9–12, 2023
- Patel Urvish, “Production, characterization of char pellets with different organic additives and its demonstration as a fuel in a forced-draft cook stove”, 4th International Conference on Recent Advances in Bio-Energy Research (ICRABR) at SSS-NIBE, Kapurthala, October 9–12, 2023

- Ramachandran Siddharth, *“Cooling Load Prediction of an off-Grid Solar Under-Ground Cold Storage: A TRNSYS Perspective”*, International Conference on Innovations in Clean Energy Technologies (ICET 2023), Energy Centre, MANIT-Bhopal, April 09, 2023

13.2 Invited Talks

- Dr Anil Kumar Dubey, delivered a lecture on, *“Biomass Based Decentralized Power Generation for Sustainable Development”*, in National conference on Achieving Sustainable Development goals in challenged Agro-Eco system organized by ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur on March 03, 2024.
- Dr Anil Kumar Dubey, delivered a lecture on, *“Employment Opportunity in Energy Sector”*, in National Conference on Perspective and Practices on Vocational Education and Training organized by Pandit Sundarlal Sharma Central Institute of Vocational Education, Bhopal on February 01, 2024.
- Dr Anil Kumar Dubey, delivered a lecture on, *“Importance of National Bio Energy Programme for Successful on ground implementation of Bio Energy”*, in the National workshop on Promoting Bioenergy, Special Focus: Green Head/steam in MSME” jointly organized by Ministry of New and Renewable Energy & Indian Biogas Association, New Delhi on December 22, 2023.
- Dr Anil Kumar Dubey, delivered a lecture on, *“Valorization of Crop Residues for Densified Fuel and Electricity”*, in ATAL Faculty Development Programme on Valorization of agro residue for Biofuels, Bio Chemicals and Bio Products organized by Tamil Nadu Agricultural University, Coimbatore on December 05, 2023.
- Er. Bhavin Soni, delivered a on *“Bioenergy Production via Thermo-Chemical Route: An Industrial Aspect”*; Under IDP-NAHEP on “Thermochemical conversion techniques for crop residue management” organized by College of Agricultural Engineering & Technology, CCS HAU, Hisar on November 2-4, 2023.
- Er. Bhavin Soni, delivered a lecture on *“Gasification Technology for Power and Thermal Application”*; Under IDP-NAHEP on “Thermochemical conversion techniques for crop residue management” organized by College of Agricultural Engineering & Technology, CCS HAU, Hisar on November 2-4, 2023.
- Dr. Gaurav Mishra, delivered a talk on *“Solid waste management and possible strategies for technology selection”* in an ISTE approved two-week STTP on “Recent Trends in Renewable Energy Systems” organized by Mechanical Engineering Department, Institute of Technology, Nirma University on July 5, 2023.
- Dr. Amrita Doshi, delivered a lecture on, *“Prospectives for the development of a circular economy around banana value chain”*, Banana Festival, organised by District Administration, Burhanpur, Madhya Pradesh, February 20 - 21, 2024.

13.3 Meetings/Workshops

- Dr. Anil Kumar Dubey, Dr. Amrita Doshi, Er. Asim Joshi, Dr. Rohit Kumar Singh,

Dr. Maku V. Rohith, Er. Bhavin Soni, Er. Urvish Patel, Er. Milan Sojitra participated in Business meet on Biomass Pellets and Briquettes Manufacturer at Navsari, organized by SPRERI, Vallabh Vidyanagar on March 14, 2024

- Dr Mukul Kumar Dubey, attended the Collaboration meet with Advait Green Energy Ltd, Axiom Canada and Gujarat Fluorochemicals Ltd on research on PEM based Hydrogen generation on February 04, 2024.
- Dr Mukul Kumar Dubey, attended the Consortia meet on Kerala Hydrogen Valley Innovation Cluster at Trivandrum, Kerala from February 01-02, 2024.
- Dr Anil Kumar Dubey, participated in a workshop on, "Current and Post Carbon Renewable Energy Systems for Rural India", organized by Institute of Rural Management, Anand on January 22, 2024.
- Dr. Anil Kumar Dubey, along with Dr. Sanjay K. S. Patel, Dr. Amruta Doshi, Dr. Rohit Kumar Singh, Er. Asim Kumar Joshi and Er. Bhavin Soni of SPRERI attended the XXVII Workshop of All India Coordinated Research Project on "Energy in agriculture and agro-based industries" organized by CIAE, Bhopal from January 28-30, 2024.
- Dr. Anil Kumar Dubey, Dr Mukul Kumar Dubey, and Er. Asim Kumar Joshi, attended the virtual meeting with Dr. Aswini from ISB to discuss upon the SPRERI technologies on January 23, 2024.
- Dr. Maku V. Rohith, attended the

National Training Programme on Biogas Production, Power Generation and Compressed Biogas Technology organized by BTDC, IIT Delhi, from January 17-19, 2024.

- Dr. Anil Kumar Dubey, and Er. Asim Kumar Joshi, attended the virtual meeting with the team of NECTOR, Delhi to discuss upon the SPRERI technologies on October 20, 2023.
- Dr Anil Kumar Dubey, Er. Bhavin Soni and Er. Urvish Patel attended 4th International Conference on Recent Advances in Bio-Energy Research (ICRABR) at SSS-NIBE, Kapurthala, October 9-12, 2023
- Er. Asim Kumar Joshi, attended the Solar thermal workshop as panelist organized by the MNRE and STFI at Atal Akshay Urja Bhavan, New Delhi, on September 13, 2023.
- Er. Asim Kumar Joshi, attended the Mid-term expert review committee meeting of the Minor Research Projects of the CVM University, Vallabh Vidyanagar, Gujarat on September 4, 2023.
- Dr. Gaurav Mishra had a meeting with M/s Saint Gobain for discussion on Biomass availability assessment for their Western Plants at Wada and Jhagadia, July 3, 2023
- Dr. Gaurav Mishra, participated as panelist the social Business Day (SBD) on June 28-29, 2023 at Birla Institute of Management Technology, Greater Noida
- Er. Asim Kumar Joshi, attended the 25th virtual meeting of the Sectional Committee MED 04 - Renewable Energy Resources of BIS on June 19, 2023.

- Dr. Gaurav Mishra, Er. Asim Joshi, Dr. Amrita Doshi, Dr. Geeta Kumari and Dr. Neha Singh attended the QRT meeting for year 2017-22 for AICRP on EAAI and CRP scheme of ICAR at held at MPKV, Rahuri on June 08 to 10, 2023
- Dr. Gaurav Mishra, Er. Asim Joshi, and Dr. Amrita Doshi visited Manav Rachna University, Faridabad to present project proposal under Strengthening, Upscaling and Nurturing Innovations for Livelihood (SUNIL) programme of DST on June 06, 2023
- Dr. Gaurav Mishra, Dr. Geeta Kumari and Dr. Barnalli Bui and SPRERI team visited DST to present project on “Torrefaction of agro-residues and its blending with coal: Up-Scaling & Demonstration” on April 27, 2023
- Dr. Gaurav Mishra attended Consultation meeting to develop Road Map for Integrated Biorefineries held on 26th April, 2023 organized by DBT.
- Dr. Gaurav Mishra had a meeting with M/s Advait Infratech Ltd for collaboration on developing Hydrogen production technologies on April 5, 2023
- Dr. Gaurav Mishra, Dr Amrita Doshi, attended the Meeting with NDDDB regarding consultation of kitchen waste Biogas plant installation on March 27, 2023.

Training/Internships/Dissertation

- Vaibhav Shivaji Bhavar, B. Tech. student of collage of Agriculture Engineering, MPKV, Rahuri, 4-month Training programme on, “**Solar Energy Technologies**”, in Solar Energy Division of SPRERI
- Ankur Patkar, B. Tech. student of collage of Agriculture Engineering, MPKV, Rahuri, 4-month Training programme on, “**Solar Energy Technologies**”, in Solar Energy Division of SPRERI
- Parmar Bhakti Yogeshbhai, Diploma student of Electronics Engineering, BBIT, Vallabh Vidyanagar, internship programme on, “**Solar Energy Technologies**”, in Solar Energy Division of SPRERI
- Dipali Balvant Singh, Diploma student of Electronics Engineering, BBIT, Vallabh Vidyanagar, internship programme on, “**Solar Energy Technologies**”, in Solar Energy Division of SPRERI
- Mistry Prachi Niteshbhai, Diploma student of Electronics Engineering, BBIT, Vallabh Vidyanagar, internship programme on, “**Solar Energy Technologies**”, in Solar Energy Division of SPRERI
- Aryan Dilliwar, B. Tech. student of Mechanical Engineering, BITS, Pilani, internship programme on, “**Solar Energy Technologies**”, in Solar Energy Division of SPRERI
- Shreyan Sandeep Kanvinde, B. Tech. student of Mechanical Engineering, BITS, Pilani, internship programme on, “**Solar Energy Technologies**”, in Solar Energy Division of SPRERI
- Shrimali Tejas Harishkumar, B. Tech. student of collage of Agriculture Engineering & Technology, Godhra, internship programme on, “**Solar Energy Technologies**”, in Solar Energy Division of SPRERI
- Thakor Dharmkumar Jayantibhai, B. Tech. student of collage of Agriculture Engineering & Technology, Godhra, internship programme on, “**Solar Energy**

Technologies", in Solar Energy Division of SPRERI

- Advait Deshmukh, B. Tech. student of Chemical Engineering, BITS, Pilani. Internship on, ***"Production of value added products from lignocellulosic biomass (Banana pseudostem)"***, in the Bioconversion Technology Division of SPRERI
- Ansh Anant, B. Tech. student of Chemical Engineering, BITS, Pilani. Internship on, ***"Development and characterization of lignin nanocomposites obtained from lignocellulose agro-waste"***, in the Bioconversion Technology Division of SPRERI
- Rohit Bharadava, B. Tech. student of collage of Agriculture Engineering & Technology, JAU, Junagadh. Internship on, ***"Bionano composite Product using MCC (MCC) Extract from rice straw"***, in the Bioconversion Technology Division of SPRERI
- Dhruvi Jagadishbhai Asodiya, B. Tech. student of collage of Agriculture Engineering & Technology, JAU, Junagadh. Internship on, ***"Development of value added product using MCC from Agri- residues for Biomedical Application"***, in the Bioconversion Technology Division of SPRERI
- Riddhi Manishbhai Gohil, M. Sc. student of Biotechnology, Shri Alpesh N. Patel PG Institute of Science and Research, Anand. Internship on, ***"Gas Fermentation strategy for synthesis of Biomethanol by Methanotropic Bacteria"***, in the Bioconversion Technology Division of SPRERI
- Aditi Hitenkumar Suthar, M. Sc. student of Biotechnology, Shri Alpesh N. Patel PG institute of science and Research, Anand. Internship on, ***"Development of simultaneous flue gas Bio sequestration and wastewater***

treatment process using Microalgae", in the Bioconversion Technology Division of SPRERI

- Darsh Deveshkumar Sharna, M. Sc. student of Biotechnology, Shri Alpesh N. Patel PG institute of science and Research, Anand. Internship on, ***"Development of lignin Nanoparticles(LNPs) based Anti-microbial composite films from agricultural waste biomass"***, in the Bioconversion Technology Division of SPRERI
- Bridget Nilesh Vagela, M. Sc. student of Biotechnology, Shri Alpesh N. Patel PG institute of science and Research, Anand. Internship on, ***"Sorbitol synthesis from MCC (MCC) of agricultural waste residues"***, in the Bioconversion Technology Division of SPRERI
- Nageshkumar B. Mehta, B. Tech. student of collage of Agriculture Engineering & Technology, JAU, Junagadh. Internship on, ***"Environmental impact of implementation of SPRERITECH cookstoves"***, in the Extension Division of SPRERI
- Mori Kuldipsinh Ranvirsinh, B. Tech. student of collage of Agriculture Engineering & Technology, JAU, Junagadh. Internship on, ***"Environmental impact of implementation of SPRERITECH cookstoves"***, in the Extension Division of SPRERI
- Prakash Damor, B. Tech. student of BVM Engg. College, V. V. Nagar, Gujarat. Internship on, ***"Development of agro-residues-based BMC Effluent treatment set-up"***, in the Thermochemical Conversion Division of SPRERI
- Harshit Shah, B. Tech. student of BVM Engg. College, V. V. Nagar, Gujarat. Internship on, ***"Development of agro-residues-based BMC Effluent treatment set-***

up”, in the Thermochemical Conversion Division of SPRERI

- Dev Parmar, B. Tech. student of Government Engineering College, Valsad, Gujarat. Internship on, **“Utilization of Banana tree waste for bio-oil generation via. Pyrolysis”**, in the Thermochemical Conversion Division of SPRERI
- Smit Parekh, B. Tech. student of Government Engineering College, Valsad, Gujarat. Internship on, **“Utilization of Banana tree waste for bio-oil generation via. Pyrolysis”**, in the Thermochemical Conversion Division of SPRERI
- C. Lakshaman Dath, M. Tech. student of Central University of Jharkhand, Ranchi. Internship on, **“Biomass assessment study in the vicinity of Vishakhapatnam and utilization of biomass for steam generation”**, in the Thermochemical Conversion Division of SPRERI
- Aiyappan Pillai, B. Tech. student of Chemical Engineering, BITS, Pilani. Internship on, **“Product characterization of banana tree waste pyrolysis”**, in the Thermochemical Conversion Division of SPRERI
- Harshit Wadhwa, M. Sc. student of Biology, BITS Goa. Internship on, **“Product characterization of rice straw pyrolysis”**, in the Thermochemical Conversion Division of SPRERI
- Deep Karangiya, B. Tech. student of College of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat. Internship on, **“Macro Level Biomass Assessment Study in Western and Southern States of India”**, in the Thermochemical Conversion Division of SPRERI
- Bhuvneshkumar Patel, B. Tech. student of College of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat. Internship on, **“Macro Level Biomass Assessment Study in Western and Southern States of India”**, in the Thermochemical Conversion Division of SPRERI
- Nikunj Chaudhari, B. Tech. student of College of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat. Internship on, **“Macro Level Biomass Assessment Study in Western and Southern States of India”**, in the Thermochemical Conversion Division of SPRERI
- Mitkumar Patel, B. Tech. student of College of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat. Internship on, **“Macro Level Biomass Assessment Study in Western and Southern States of India”**, in the Thermochemical Conversion Division of SPRERI
- Dhritvi Mori, B. Tech. student of College of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat. Internship on, **“Macro Level Biomass Assessment Study in Western and Southern States of India”**, in the Thermochemical Conversion Division of SPRERI
- Prakash Dodiya, B. Tech. student of College of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat. Internship on, **“Macro Level Biomass Assessment Study in Western and Southern States of India”**, in the Thermochemical Conversion Division of SPRERI
- Nisarg Dedhiya, B. Tech. student of College of Agricultural Engineering and Technology, AAU, Godhara, Gujarat. Internship on, **“Demonstration of Groundnut Shell as a Biofuel Using Fluidized-Bed Gasification System”**, in the Thermochemical Conversion Division of SPRERI

Visitors

- Mr. Ashish Vaishnav, Executive Director, Gangotree Energy Projects Pvt Ltd., Pune visited on March 27, 2024 for demonstration of Biomass Pelleting machine.
- Dr. Kantha Devi, Dean, Marwari University, Rajkot along with her staff members visited SPRERI on March 21, 2024 for discussion on setting up of the prototype of Solar drier, Solar refrigerator, solar cooking system in our agriculture field.
- Mr. Sumendar Singh, General Manager, National Bank for Agriculture and Rural Development with his team consists of General Manager, Deputy General Managers, and Asst. General Managers of 25 districts visited SPRERI on March 19, 2024
- Dr. V.C. Patil, Former Dean, University of Agricultural Science, Karnataka visited SPRERI on January 28, 2024
- Dr V M Modi, Dean of Renewable Energy and Environmental Engineering along with the academic staff from Sardarkrushinagar Dantiwada Agricultural University visited SPRERI on December 19, 2023 to explore opportunities in the field of Renewable Energy and Environmental Engineering
- Dr. Vinod Kumar Bhargav (Project Coordinator, All India Coordinated Research Project on Energy in Agriculture and Agro based Industries) visited SPRERI on 18 and 19, October 2023.
- Captain Vineet Ranawat and Mr. Sudhakiran from Kanha Ashram, Hyderabad visited SPRERI on September 19, 2023
- Dr Sanjay Jain, Associate Professor, Mechanical Engineering and STTP coordinator, Nirma University along with thirty academic staff participating in Indian Society for Technical Education approved two-week Short-Term Training Programmes on “Recent Trends in Renewable Energy Systems” organized by Nirma University Ahmedabad visited SPRERI on July 7, 2023
- Shyam Gupta, Head Supply Chain Management, Anandrao Deshmukh – Senior Manager Purchase, Balakrishnan, Senior Research Scientist, Saint-Gobain Research India, Apurv Ghugare- Indian Institute of Technology, Madras visited on July 3, 2023
- Dr. Zaheer, Scientist H, Head-Petroleum Management, Dr. Akash Davda, Scientist F, Head-New Technology Management, Dr. Rasheed, Scientist E1, Head-Environment Management from Gujarat Energy Research and Management Institute, Gujarat visited SPRERI on July 2023
- Dr Kuyer Thaker, DGM, Process Excellence lab of M/s. Alembic Pharmaceuticals Limited, Vadodara, along with his technical team visited SPRERI on May 6, 2023
- Dr Sudarshan Suryawanshi, Chief Operating Officer., Axiom India (Canada) visited SPRERI on February 7, 2024

The Team

Director

- Dr Anil Kumar Dubey
- Dr Gaurav Mishra (till 11/08/2023)

Solar Energy Division

- Dr Mukul Kumar Dubey, Principal Scientist, Head
- Er Asim Kumar Joshi, Senior Scientist
- Dr Ravi Kant, Associate Scientist
- Er Milan Sojitra, Junior Engineer
- Mr Mahendra Padhiyar, Jr Lab Assistant
- Mr Mukesh Jadhav, Helper
- Dr Siddharth Ramachandran (till 21/08/2023)

Bio-conversion Technology Division

- Dr Maku V Rohith, Senior Scientist, In-charge
- Dr Neha Singh, Senior Scientist
- Dr Anand Narayanasamy, Research Associate
- Mrs Aesha Patel, JRF
- Ms Drishya P K, JRF
- Ms Mareena Jose, JRF
- Ms Bilwa Chandekar, JRF
- Mr Ashok Harijan, Lab Attendent
- Mr Ashok Mochi, Helper
- Mr Harman Parmar, Helper
- Mrs Manjula Vadhel, Helper
- Dr Sanjay K S Patel, Advisor & Consultant (till 29/02/2024)
- Mr Paresh Thakur, Technical Assistant (till 07/07/2023)
- Mr S Suresh Kumar, JRF (till 27/07/2023)

Thermo-chemical Conversion Technology Division

- Er Asim Kumar Joshi, Senior Scientist, In-charge
- Dr Rohit Kumar Singh, Senior Scientist
- Er Bhavin Soni, Associate Scientist
- Er Urvish Patel, SRF
- Mr Ashok Patel, Helper
- Dr Geeta Kumari, Senior Scientist (till 08/09/2023)
- Dr Barnali Bhui, Senior Scientist (till 30/06/2023)

Technology Transfer & Extension Division

- Dr Amrita Doshi, Senior Scientist, In-charge
- Mr Paresh Mer, Program officer
- Mr Minesh, Technical Assistant
- Mr Shailesh Solanki, Helper

Administration & Finance

- Mr Bipin K Patel, Account & Admin Officer
- Mr Hashmukh Vaghela, Jr. Office Asstistant
- Mr Mayur Parmar, PA to Director
- Mr Chetan Parmar, Sr. Account Assistant
- Mr Harshad Suthar, Draftsman
- Mr Bhupendra Prajapati, Electrician
- Mr Dahya Harijan, Jr. Mechanic
- Mr Rajesh Machi, Driver
- Mr Ramesh Bhoi, Driver
- Mr Bhupendra Parmar, Helper

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 - 2024

FUNDS & LIABILITIES	31/03/2023	31/03/2024	ASSETS	31/03/2023	31/03/2024
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	₹ 17,166,925.67	₹ 10,327,209.67	2. Electric Fittings	₹ 162,350.85	₹ 162,350.85
Add / Less during the year	-₹ 6,839,716.00	₹ 4,763,637.00	3. Mobile Phone	₹ 19,600.00	₹ 19,600.00
(As per Schedule - 4)	₹ 10,327,209.67	₹ 15,090,846.67	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	₹ 126,748,051.51	₹ 129,342,359.51	6. New Jeep - GJ-23-GA-0488	₹ 834,000.00	₹ 834,000.00
Add : During the year	₹ 2,594,308.00	₹ 959,885.00		₹ 2,922,728.47	₹ 2,922,728.47
(As per Schedule - 1)	₹ 129,342,359.51	₹ 130,302,244.51	PROJECT EQUIPMENT	₹ 129,342,359.51	₹ 130,302,244.51
Gratuity Fund	₹ 6,643,040.32	₹ 6,691,819.19	INVESTMENT		
EAR MARKED FUND			Fixed Deposit (As per Schedule -2)	₹ 32,241,414.00	₹ 32,561,935.00
1. Building Fund Provision	₹ 3,532,595.00	₹ 3,532,595.00	Deposit in LIC - Gratuity Scheme	₹ 6,643,040.32	₹ 6,691,819.19
2. Research & Development Fund	₹ 10,460,434.83	₹ 10,460,434.83		₹ 38,884,454.32	₹ 39,253,754.19
3. Contingent Development Fund	₹ 140,070.00	₹ 140,070.00	LOANS & ADVANCES		
4. Depreciation Fund	₹ 6,884,896.30	₹ 6,988,937.30	1. Tax Deduction at Source	₹ 793,505.06	₹ 689,484.06
5. Endowment Fund (Hari Om Ashram)	₹ 1,514,118.75	₹ 1,514,118.75	2. Telephone Deposit	₹ 20,313.00	₹ 20,313.00
6. Share & Care Fund	₹ 160,477.00	₹ 160,477.00	3. CGM Deposit(Oil Diesel & Petrol)	₹ 12,400.00	₹ 12,400.00
7. Maint. Fund (Core Grant)	₹ 762,173.00	₹ 762,173.00	4. Indian Oxyzen Ltd., Deposit	₹ 4,252.94	₹ 4,252.94
8. Depreciation Investment Fund	₹ 478,006.00	₹ 478,006.00	5. Mobile Phone Deposit	₹ 4,680.00	₹ 4,680.00
9. Staff Welfare Fund	₹ 1,540,642.95	₹ 1,782,628.95	6. Broad Band Security Deposit	₹ 3,000.00	₹ 3,000.00
10.Quiz Prog. Fund	₹ 61,175.00	₹ 61,175.00	7. Gas Cylinder Deposit	₹ 10,350.00	₹ 10,350.00
11.Donation (Gen.)	₹ 2,172,674.00	₹ 2,318,674.00	8. Security Deposit(GEB - New DP)	₹ 100,920.00	₹ 100,920.00
(As per Schedule - 5)	₹ 27,707,262.83	₹ 28,199,289.83	9. Loan to Staff & Advance to Project	₹ 729,642.00	₹ 834,642.00
			10.Intrest Accrued	₹ 609,922.00	₹ 1,913,980.00
Balance as per last Balance Sheet				₹ 2,288,985.00	₹ 3,594,022.00
Balance as per last Balance Sheet	-₹ 31,577.65	₹ 14,206.80	BALANCE :		
Add/ Less : - As per Inc. & Exp. A/c	₹ 45,784.45	₹ 1,983,717.53	Bank Balance (As per Schedule - 3)	₹ 1,631,948.03	₹ 7,234,009.56
Add:- Surplus	₹ 14,206.80	₹ 1,997,924.33	Cash Balance	₹ 46,273.00	₹ 58,035.00
				₹ 1,678,221.03	₹ 7,292,044.56
TOTAL	₹ 175,116,748.33	₹ 183,364,793.73	TOTAL	₹ 175,116,748.33	₹ 183,364,793.73

Date :- 06/07/2024
Place :- Vallabh Vidyanagar


Accounts Officer




Director




Chartered Accountants

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

Acronyms

AICRP	All India Coordinated Research Project	ILs	Ionic Liquids
AP	Acidification Potential	ISO	International Organization for Standardization
CCUS	Carbon Capture Utilization and Sequestration	ITI	Industrial Training Institute
CFC	Chlorofluorocarbon	JTDS	Jharkhand Tribal Development Society
CNC	Cellulose Nanocrystals	LCA	Life Cycle Assessment
COP	Coefficient of Performance	LCIA	Life Cycle Impact Assessment
CSR	Carbon-to-Steam Ratio	LNP	Lignin Nanoparticles
DBT	Department of Biotechnology	LPG	Liquefied Petroleum Gas
DCB	Dichlorobenzene	MCC	MCC
DST	Department of Science and Technology	MNRE	Ministry of New and Renewable Energy
EDX	Energy Dispersive X-ray Spectroscopy	MoU	Memorandum of Understanding
EP	Eutrophication Potential	MSD	Micro Solar Dome
EPD	Department of Energy and Petrochemicals	JTDS	Jharkhand Tribal Development Society
ETP	Ecotoxicity Potential	LCA	Life Cycle Assessment
FES	Foundation for Ecological Security	MT	Metric Tonne
FTIR	Fourier Transform Infra-Red Spectroscopy	NADES	Natural Deep Eutectic Solvent
FWEO	Filtrate of Waste Engine Oil	NP	Nanoparticle
GAA	Glacial Acetic Acid	PCM	Phase Change Material
GEDA	Gujarat Energy Development Agency	PNG	Piped Natural Gas
GHI	Global Horizontal Irradiance	PUFA	Polyunsaturated Fatty Acid
GSBTM	Gujarat State Biotechnology Mission	PV	Photovoltaic
GUJCOST	Gujarat Council of Science and Technology	PVA	Polyvinyl Alcohol
GWP	Global Warming Potential	PVT	Photovoltaic-thermal
HBA	Hydrogen Bond Acceptor	RE	Renewable Energy
HBD	Hydrogen Bond Donors	RPM	Rotation per Minute
HTP	Human Toxicity Potential	RSM	Response Surface Methodology
ICAR	Indian Council of Agricultural Research	SC	Scheduled Caste
		SCSP	Scheduled Caste Sub Plan
		SDG	Sustainable Development Goals
		SEM	Scanning Electron Microscope
		SHG	Self-Help Group
		SS	Stainless Steel
		TEM	Transmission Electron Microscope

Technologies for Commercialization

- Portable double-glazed solar dryer
- Thermal energy storage based Indirect solar dryer
- Standalone type PV integrated solar low tunnel dryer
- Forced circulation solar cabinet dryer
- Solar-biogas hybrid cold storage system
- Thermal battery-based solar refrigerator
- Solar PV driven thermal energy storage integrated micro cold storage
- 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 dish-based cooking system
- Thermal energy storage integrated solar Fresnel lens-based cooking system
- Solar photovoltaic-thermal (PVT) hybrid collector for air heating
- Nanofluid for performance enhancement of solar thermal collectors
- Solar-based wax melting system
- Single-axis sun tracker for photovoltaic panels
- 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

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



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