

SPRERI
Striving for Excellence

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE


Annual Report 2021-22





DEVELOPING RENEWABLE ENERGY TECHNOLOGIES
VIALE FOR SOCIETY SINCE 1979


Sardar Patel Renewable Energy Research Institute

 Post Box No. 2, Vallabh Vidyanagar - 388 120, Gujarat, India

 Phone : 02692 - 231332, 235011

 Fax : 02692 - 237982

 E-mail : info@spreri.org; director@spreri.org

 Website : www.spreri.org

Contents

	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	10
3. Thermo-chemical Conversion Technology Division	15
4. Training and Awareness Creation	21
5. Technology Demonstration	23
6. Consultancy Projects	29
7. Technology Transfer	29
8. Patent	29
9. Memorandum of Understanding	29
10. Recognitions and Academic Activities	30
<i>Graduate & Post-graduate Dissertations</i>	30
11. Publications	31
12. Conferences, Meetings & Workshops, National & International Conferences	32
<i>Invited Lectures</i>	32
<i>Meetings/Workshops</i>	33
<i>Webinars/Seminars</i>	37
<i>Presentations</i>	38
13. Visitors to the Organization	40
14. Team	41
15. Balance Sheet	42
16. Acronyms	43
17. List of Technologies for Commercialization	43
18. Acknowledgements	44



List of Figures

- Fig. 1:** Mass fraction profile of PCMI
- Fig. 2:** Temperature profile for green chilly drying test
- Fig. 3:** Revamped laboratory-scale drying test set-up
- Fig. 4:** Air temperature profile during drying of tomato slices @ 80°C
- Fig. 5:** Air relative humidity profile during testing of tomato slices @ 80°C
- Fig. 6:** Solar biomass hybrid drying setup
- Fig. 7:** Arrangement for evaporation area enhancement within the basin
- Fig. 8:** CPC heat pipe solar still (prototype-2)
- Fig. 9:** Loading of bananas in crates after chemical wash
- Fig. 10:** Loading Day cold room temperature and machine operation trend
- Fig. 11:** Comparison of bananas before and after ripening
- Fig. 12:** Front door solar refrigerator with 15 kg ice bank on top
- Fig. 13:** CFD simulation of existing refrigerator chamber for the winter season
- Fig. 14:** CFD simulation of existing refrigerator chamber for the summer season
- Fig. 15:** Temperature profile on grid supply (12 h operation)
- Fig. 16:** Temperature profile on grid supply (6 h operation; with thermostat)
- Fig. 17:** Scenario comparison of supplier-1 and supplier-2 absorption chiller-based plant with supplier-3 adsorption chiller-based plant
- Fig. 18:** Temperature variations for a year at different underground depths
- Fig. 19:** TRNSYS model of cold storage with adsorption chiller
- Fig. 20:** Nanofluid with 0.5% of soot particles and DI water
- Fig. 21:** Bio-methanol studies using *Methylobacillus flagellates*
- Fig. 22:** LMBR to bio-hydrogen and aquafeed
- Fig. 23:** Ex-situ treatment of rice straw using novel microbial consortia
- Fig. 24:** Valorization of lignin for different applications : [A] Lignin nano-particles into nano-fibers and carbon fiber, [B] Lignin nano-particles for anti-corrosion application: (a) Without coating (b) Epoxy control (c) Indulin nano-particle coated d. Lignin nano-particle coated, [C] Lignin nano-particles into nano-gel: (a) nano-gel (b) dried nano-gel (c) water absorbed nano-gel
- Fig. 25:** Schematic arrangement of in-situ utilization of pyro-gas
- Fig. 26:** Emission measurement set-up



- Fig. 27:** Image of the installed pilot-scale (5 kg) reactor for the production of activated carbon from bio-char of agro-residues
- Fig. 28:** Students visit at SPRERI
- Fig. 29:** Farmers visited SPRERI during the Mela
- Fig. 30:** National campaign on farm mechanization programme at Matar and Daloli village
- Fig. 31:** One-week online training
- Fig. 32:** Solar walk-in type dryer installation and drying of jalbrahmi
- Fig. 33:** Discussion with students
- Fig. 34:** Traditional and SPRERITECH cookstove at R.S. Gruh Udyog – Rice papad making industry
- Fig. 35:** Diesel stove and SPRERITECH IBC at Jay Randhod Nasta House, Bhimpura
- Fig. 36:** Construction of solid-state biogas plant at Ajarpura, Laljipura and Shardapura village
- Fig. 37:** Demonstration of IBCS and Micro solar dome at SPRERI during exposure visit and tribal area of Dang during rural orientation programme
- Fig. 38:** Awareness and demonstration of RE gadgets/devices at Tribal Research-cum-Training Centre, Dahod
- Fig. 39:** ACF KVK demonstration programme at Kodinar Gir Somnath
- Fig. 40:** Biogas plant at Vatsalya International School, Borsad
- Fig. 41:** Biogas plant at IRMA, Anand



List of Tables

- Table 1:** Properties and charging time of two different PCM
- Table 2:** Test results for drying green chilly and tomato
- Table 3:** Specification of the lab-scale drying test set-up
- Table 4:** Results for drying at 0.5 ms^{-1} air flow rate
- Table 5:** Drying rate observed for drying at 0.5 ms^{-1} air flow rate
- Table 6:** Performance of solar hybrid dryer for tomato drying (8 pieces long cut)
- Table 7:** Vapor compression machine operation details
- Table 8:** Efficiency of the solar thermal collector with and without nanofluid at different flow rates
- Table 9:** Comparison of the trial runs of the FBG system with the previously recorded average values
- Table 10:** Data on (with and without in-situ utilization of pyro-gas) in a pilot-scale continuous pyrolysis system
- Table 11:** pH, solid content and calorific value of bio-oil obtained from fast pyrolysis of sawdust (SD), groundnut shell (GNS) and cotton stalk (CS) in catalytic and non-catalytic mode
- Table 12:** Proximate analysis, calorific value and bulk density of the bio-char produced from fast pyrolysis of sawdust, GNS and CS in non-catalytic mode
- Table 13:** Emission profile of both systems
- Table 14:** Cost analysis of both fuel processing technologies for a 1,00,000 kcal/hr capacity system
- Table 15:** Product yield MBn and cost of different activated carbon samples
- Table 16:** Thermal efficiency and power output of cookstove with char pellets
- Table 17:** Pre-post data of dhabha size IBCS
- Table 18:** Kitchen waste-based biogas plants details
- Table 19:** Field performance of the kitchen waste-based biogas plants



Highlights of the Year

Over the years, SPRERI has developed various technologies suitable for rural/tribal areas and of national interest. SPRERI has been involved in implementing these technologies in the field to bring positive changes in the lives of the populace. Technologies like, improved biomass cookstoves, patented bio-methanation processes, various kinds of biomass gasifiers, solar dryers etc., are either commercialized or ready for technology transfer for large-scale commercialization.

Further, SPRERI in-line with the Government of India's broad agenda continues its research and development in technologies and/or processes in the renewable energy sector and solid waste management.

At SPRERI, the thermo-chemical conversion division, in one of the projects, is working on the conversion of various agro-residues to bio-char and eventually to activated carbon production as a value-added product. A good quality activated carbon is obtained and work is underway to design and develop a process for a continuous activated carbon production system from bio-char. More detailed efforts on the conversion of agro-residues to bio-oil and its use are also in the research phase. In addition, the division is implementing an in-house developed fluidized bed gasification system in a few Poha-making industries under the Department of Science and Technology, Govt. of India sponsored project.

The bio-chemical conversion division, post patenting an "Odour-free process for handling of organic solid wastes for bio-methanation and simultaneous production of solid bio-fuel/manure", has implemented a Department of Bio-Technology, Govt. of India sponsored 3.5 TPD bio-methanation plant at Karamsad Hospital to replace their PNG load at Surbhi canteen. Under the project, SPRERI is also focusing on establishing a model for the segregation of food waste, its collection, transportation, and its scientific treatment. SPRERI has joined hands with many like-minded organizations i.e., Local NagarPalikas, CARPE-Aurangabad, GMM Pfaudler-Karamsad, etc. in executing the project.

The solar energy division is working on introducing diesel exhaust-based nano-particles in solar thermal products and has achieved an increase of ~18% of thermal efficiency. The team is also working on developing thermal storage material-based cooking devices suitable to meeting the thermal need of a family of four people for their full day cooking.

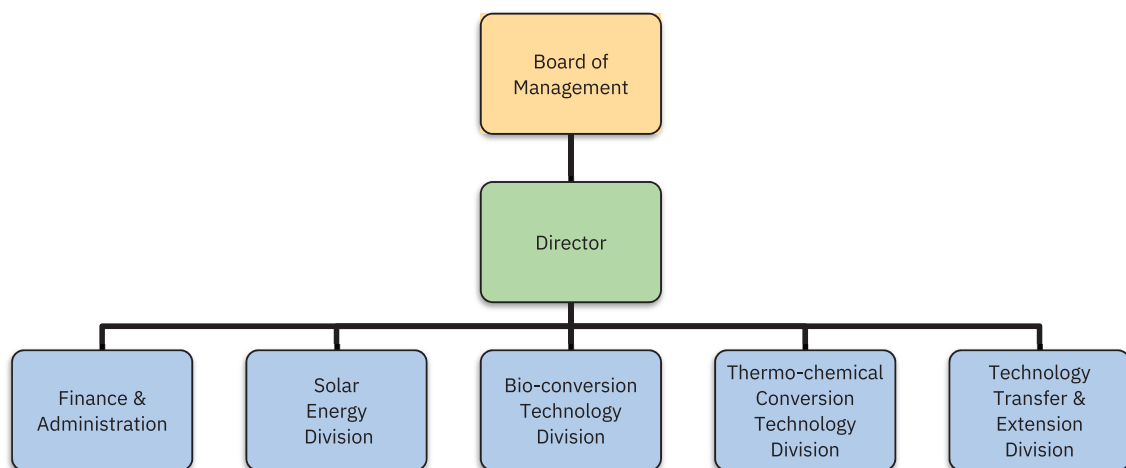
SPRERI has extended its resource personnel in various training programs throughout the year. The extension division has installed more than 120 no's of SPRERI developed improved biomass cookstoves in different parts of Gujarat.

The annual event on awareness creation on renewable energy was organized at SPRERI on 25/3/2022. More than 200 persons, primarily students, farmers, and Women Self Help Groups from all over Gujarat, participated in the event.



The Organization & Structure

Sardar Patel Renewable Energy Research Institute (SPRERI), established in 1979, is an autonomous and not-for-profit organization managed by a Board comprising leading technologists, scientists, industrialists, and representatives of Central and State Governments. It is recognized by the Department of Scientific and Industrial Research, GoI, as a Scientific and Industrial Research Organization. It is also approved as a Research Association for the purpose of clause (ii) of sub-section (1) of section 35 of IT Act, 1961. It generates most of its operating funds through projects assigned to it on merit by government and non-government organizations. SPRERI's service activities like consultancy, technology evaluation, testing, and training supplement project funds to make it self-supporting. As a renowned renewable energy (RE) research institution it is recognized for post graduate research by many other academic institutions and universities. Solar energy, bio-conversion and thermo-chemical conversion of biomass are the three major fields of specialization at SPRERI. Many renewable energy devices and systems developed at SPRERI are now manufactured by selected industries and supplied to end users. In addition, the promotion of renewable energy technologies is pursued through field evaluation and demonstrations, training and entrepreneurship development, awareness programmes and integrated development of selected tribal villages.



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 be a centre of excellence for research and development, education and training in the field of renewable energy, with strong capability to provide and promote user and environment friendly and commercially viable renewable energy technologies to mitigate energy shortage and damage to the environment.



Board of Management

Chairman:

Dr. Amrita Patel Trustee, Charutar Arogya Mandal, Karamsad

Members:

Prof. B.S. Pathak Ex-Director, SPRERI and Energy Consultant
KC-5, Kavi Nagar, Ghaziabad

Shri P.C. Amin Director, Elecon Group of Companies
M/s Elecon Engineering Co. Ltd., Vallabh Vidyanagar

Dr. Kanchan K. Singh Assistant Director General (Engg)
Indian Council of Agricultural Research, New Delhi

Shri Deepak Joshi Head, Electronics & Controls Systems Division
M/s Jyoti Limited, Vadodara

Shri J.S. Joshi Deputy Secretary (NCE), Petro & Renewable Energy, Energy &
Petrochemicals Dept., Govt. of Gujarat, Gandhinagar

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

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

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

Member-Secretary:

Dr. Gaurav Mishra Director, SPRERI, Vallabh Vidyanagar



1.1 Solar cooking

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

CFD study of the thermal storage device was carried out. CFD analysis was done for PCM1 (comprises mix of K and Mg) and PCM2 (has base of Na). Table 1 shows the properties of selected PCMs.

Table 1 Properties and charging time of two different PCM

S.N.	Properties	PCM1	PCM2
1	Melting point	435 °C	304 °C
2	Heat of fusion	351 kJ/kg	172 kJ/kg
3	Volume of PTS device	3.61 L	
4	Charging time	42 min	52 min
5	Mass of PCM in PTS device	7.6 kg	8.14 kg
6	Stored latent heat	2668 kJ	1400 kJ

The charging time and latent heat storage capacity of PCM1 is 42 min, 2668 kJ, and PCM2

is 52 min, 1400 kJ respectively for the designed PTS device. Fig. 1 represents the mass fraction contour at a different time for PCM1 for charging with the top plate at a temperature of 600°C. Based on the CFD studies the design is found suitable and its fabrication is in progress. The tracker modification is also in progress to integrate the fresnel lens with the thermal storage device.

1.2 Solar Drying

Thermal energy storage-based indirect solar dryer

Load testing of the drying system was carried out with thermal storage in a single-pass mode for drying blanched green chilly (un-punctured) and tomato (wedge shape 4 cut medium size). An electric heater is used as a backup for night-time operation. The tests were started at around 11:00 am by loading the drying chambers. The thermal storage was kept charged before initiating the test. The testing was continued overnight till the difference in weight loss in two successive readings became negligible. The temperature profile observed for testing green chilly is shown in Fig. 2. The temperature

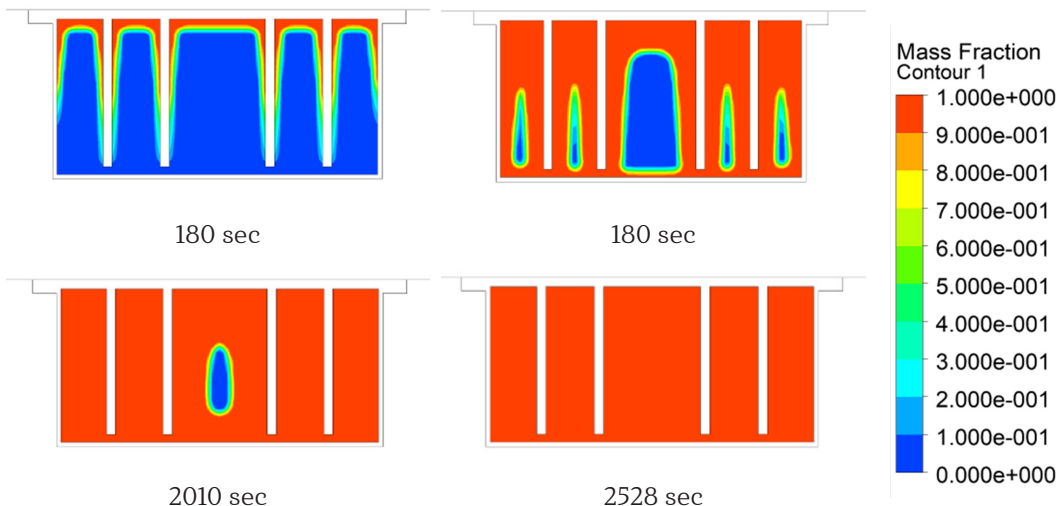


Fig. 1 Mass fraction profile of PCM1

in the drying chamber was maintained above or near 55°C during the entire test. The sudden temperature drops are due to the opening of the drying chamber for sample weighing. The details of drying time taken, and electric heat utilized are given in Table 2. Cost economics for green chilly drying is evaluated considering a shelf life of complete drying system as 10 years. The simple payback estimated was 3.8 years. For the rest of the life of the system, the user will have a profit of Rs 3,30,813/- without considering any inflation in rates.

The system modification for air recirculation has been done. Pneumatic actuator-driven air dampers and a high-temperature humidity sensor-based controller is installed to control the damper operation. The testing of the system in recirculation mode is in progress.

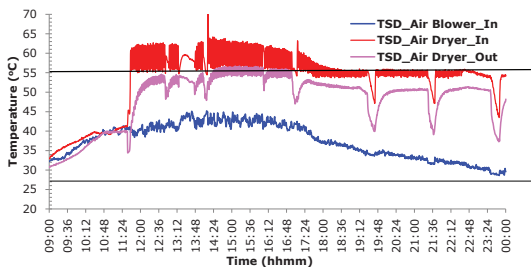


Fig. 2 Temperature profile for green chilly drying test

Laboratory-scale drying test set-up and data generation on drying characteristics of various agro-produce

- The available non-working laboratory-scale drying test set-up (Fig. 3) (developed earlier by Dr. S. K. Philip and team) was

made operational and the required instrumentation and control automation was carried out. The existing heating coil was replaced with a better design heating coil, which sustains against vibrations, and long-run operations, and does not break in the case of no airflow. The specifications of the system are given in Table 3 below.

Table 3 Specification of the lab-scale drying test set-up

Components	Specification
Centrifugal blower	0 to 250 Nm ³ h ⁻¹ , MOC SS material
Drying chamber size	500 x 240 x 65
Drying tray make & size	SS make; 350 x 230
Air carrying pipe diameter	1 inch
Speed/air flow Controlling	0 to 1.5 ms ⁻¹ range
Electric heater with Temp. controller	0 to 80°C, 2 kW 01 nos.
Automation controller	Hot air temperature control based on controlling electric heater operation

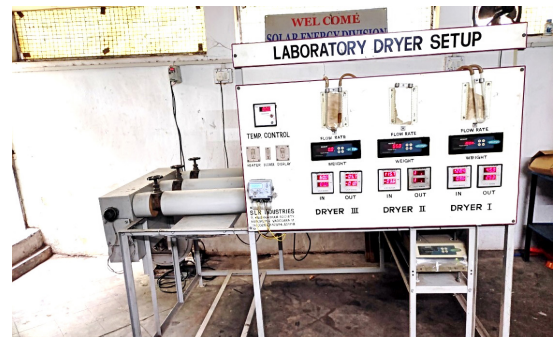


Fig. 3 Revamped laboratory-scale drying test set-up

Table 2 Test results for drying green chilly and tomato

Produce	Green chili (blanched unpunctured)		Tomato (4 piece wedge shape)	
	solar dryer @ 55°C)	Open sun	Solar dryer (@ 55°C)	Open sun
Dried in	solar dryer @ 55°C)	Open sun	Solar dryer (@ 55°C)	Open sun
Initial weight, kg	35.00	0.70	16.00	3.00
Final weight, kg	4.95	0.16	0.98	0.175
Time taken for drying, h	15 (6 h on solar)	19	13 (6 h on solar)	18
Electricity utilized, kWh	115.30	--	107.20	--

- Testing was done for drying tomatoes and fenugreek in different sizes and at different air temperatures. The results are given in Tables 4 & 5. It can be seen that with an increase in air temperature the drying time reduced and vice-versa the electricity consumption increased.

Table 4 Results for drying at 0.5 ms⁻¹ air flow rate

Sample type	Sample initial weight, (g)	Drying time, (h)		
		@ 60±2°C	@ 70±2°C	@ 80±2°C
8-piece wedge tomato	600	14	12	11
Slices 4-5 mm tomato	355	7.5	6.0	5.5
Fenugreek leaf and tender stem	100	3	2.25	1.5

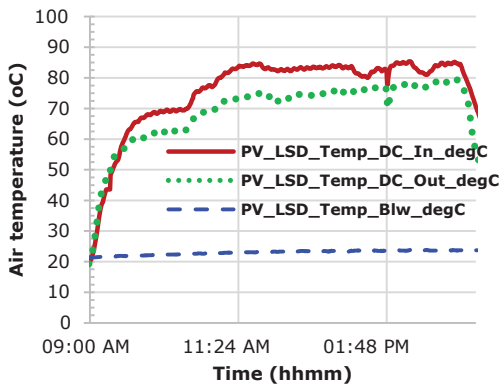


Fig. 4 Air temperature profile during drying of tomato slices @ 80°C

- The air temperature change and relative humidity change profile in the case of tomato slice drying at 80 °C is shown in Fig. 4 & 5. Under all the tests, it was observed that the reduction in the temperature of hot air was in the range of 0° to 15°C, and the gain in relative humidity was in the range of 0 to 10% RH. From these findings, it can be concluded that for efficient drying, the

exhaust hot air can be further recirculated for drying the products. Further testing for drying of items, i.e. turmeric, red beet, Indian blackberry, and lemon not tested earlier is in progress.

Table 5 Drying rate observed for drying at 0.5 ms⁻¹ air flow rate

Sample type	Sample initial weight, g	Drying rate (gh ⁻¹)		
		@ 60±2°C	@ 70±2°C	@ 80±2°C
8-piece wedge tomato	600	38.5	45.0	49.0
Slices 4-5 mm tomato	355	42.6	53.2	58.0
Fenugreek leaf and tender stem	100	30.0	40.0	60.0

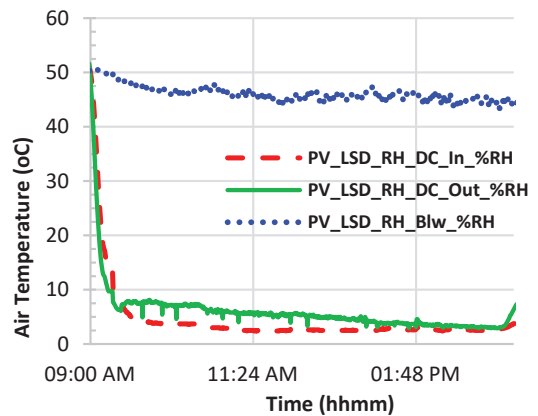


Fig. 5 Air relative humidity profile during testing of tomato slices @ 80°C

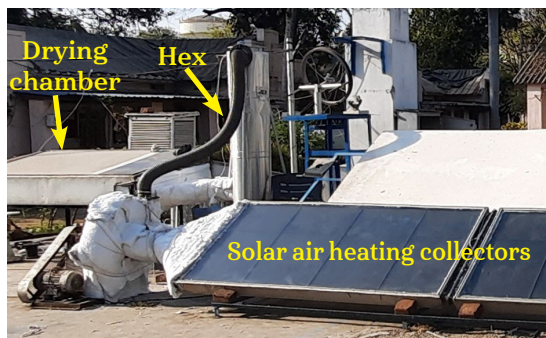
Integration of solar air heating collectors and SPRERITECH improved biomass stove to study continuous drying of tomato

In order to evaluate the time taken, fuel consumption, and cost of the dried product for continuous drying in hybrid mode (solar + biomass) compared to open sun drying, a comparative test was carried out. The setup is shown in Fig. 6. The performance data of the system compared to open sun drying is given in Table 6.

Table 6 Performance of solar hybrid dryer for tomato drying (8 pieces long cut)

Parameter	Solar + biomass Dryer	Open Sun
Initial weight, kg & cost	20 (@ ₹ 25/kg = ₹ 500)	20 (@ ₹ 25/kg = ₹ 500)
No. of trays	4	4
Load per tray, kg	5	5
Final dried product, kg	1.3	1.0
Drying time, h (including night time)	23	85 (3 whole day + 13 h)
Drying time, h (not including night time)	--	30
Total wood utilized, kg & cost	38.35 (@ ₹ 5/kg = ₹192)	--
Avg. drying temperature, °C	60.9	--
Avg. Ambient Temp., °C	23.37 (whole day avg.)	31.29 (avg. from 900 to 1700)
Air flowrate, m ³ /h	424.4	Natural convection
Electricity consumption, kWh & cost	17.25 (@ ₹ 5.5/unit = ₹ 94.9)	--
Cost per Kg dried product (without manpower cost)	(₹ 500 + ₹ 192+ ₹ 94.9) /1.3 = ₹ 607.8/kg	₹ 500/1 = ₹ 500/kg

- From the test, it is evident, that for the total time of 85 hrs (open sun case), through hybrid mode testing one can have 3.8 times more production in the same time.
- Considering the selling price of ₹ 1000/kg dried product. The user will have a revenue of ₹ 500/kg in 3.5 days in the case of open sun drying, whereas in the case of solar hybrid drying the revenue will be ₹ 409.25/kg per day i.e. ₹ 1432.37 in 3.5 days. i.e. ₹ 932.37 more.
- Also, compared to open sun drying, there will be no product losses towards mould formation and spoilage.

**Fig. 6** Solar biomass hybrid drying setup

1.3 Solar Desalination

Solar compound parabolic concentrator (CPC) for desalination of groundwater

A CPC with heat pipe (HP) collector was developed by providing heat pipe and conducting aluminum foil in the evacuated tubes of the CPC collector. To run water through the collector and piping, a 19 W DC pump was installed inline. To further enhance the distillate production a black cloth was provided inside the basin at a certain height, to enhance the overall area for water evaporation. The arrangement made is as shown in Fig. 7. A more reliable weatherproof transparent polycarbonate sheet was selected over a flexible LDPE sheet (Fig. 8) and a new cover of a rectangular pyramid shape was designed, fabricated, and integrated with the current system.

The optical efficiency of the CPC-HP integrated into the water storage tank (CPCHP-HWS) system was obtained as 44.35% and the daytime heat loss coefficient obtained was

0.334 Wm⁻²K⁻¹. The amount of thermal energy stored by tank water was evaluated at around 6.81 kW, which was equivalent to evaporating around 10.85 L of water.



Fig. 7 Arrangement for evaporation area enhancement within the basin



Fig. 8 CPC heat pipe solar still (Prototype-2)

The performance of the developed CPC HP still was carried out for a 10 L load with the pump operational for 15 min and off for 15 minutes from (09:00 am to 05:00 pm). The maximum distil water production observed was 5 L for 24 h cycle i.e. 2.19 L/m². This is lower than expected. It is to be noted that in the case of polycarbonate sheet the thermal conductivity is lower 0.22 to 0.24 Wm⁻²K⁻¹ compared to that of LDPE sheet 0.33 Wm⁻²K⁻¹. The lower performance is because of lower normal radiation, lower ambient temperature, and lower thermal conductivity of condenser cover i.e. polycarbonate sheet. However, compared to a simple FRP-based solar still, the performance is observed to be 82% more.

Further modifications on improvement in the system design to improve its performance are in progress.

1.4 Solar Refrigeration

Thermal energy storage for solar-driven cold storage

Load testing on the grid supply

A load test was carried out for banana ripening. The bananas were washed in a ripening-inducing chemical solution before loading them in the cold room. The temperature in the cold room was maintained at 19 ± 1 °C. Fig. 9 shows the loading of bananas in crates after ripening chemical wash. Details of testing are as follows :

Test duration 6 days; Loading time Day 1, 1615;
Quantity of banana ~ 810 kg



Fig. 9 Loading of bananas in crates after the chemical wash

Fig. 10 represents the cold room temperature and machine operation trend from initial loading till the time when setpoint was achieved and maintained. Table 7 gives details of the total no. of hours the vapor compression machine was operated daily and electricity used to operate the machine (in kWh) during this ripening experiment. The comparative photo of bananas when put into a cold room for ripening on day 1 and when taken out on day 6 morning is shown in Fig 11.

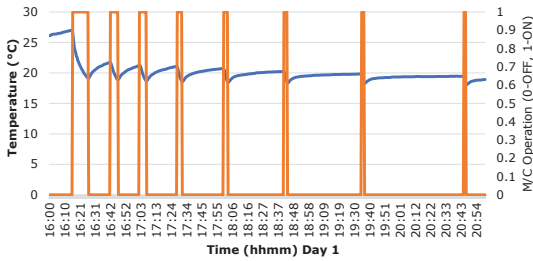


Fig.10 Loading Day cold room temperature and machine operation trend

Table 7 Vapor compression machine operation details

Date	No. of minutes operated
Day 1	34
Day 2	59.5
Day 3	85.5
Day 4	116
Day 5	125.5
Day 6	106
Total Minutes Operated	526.50 minutes
Total Hours Operated	8.77 hours
Total Electricity Consumption	38.00 kWh



Bananas on Day 1



Bananas on Day 6

Fig.11 Comparison of bananas before and after ripening

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

- Under All India Coordinated Research Project on Renewable Energy Sources, the solar refrigerator (capacity 80 L) was developed for the storage of medicine and other perishable products. It was demonstrated that 15 kg of ice can be

generated on a Solar PV supply with battery backup in this refrigerator. This ice will provide cooling to maintain temperature overnight. Further refinement of this refrigerator/development of a new model is being done for a more reliable system wherein the cooling can be achieved at a faster rate. The available solar refrigerator is as shown in Fig. 12.



Fig. 12 Front door solar refrigerator with 15 kg ice bank on top

- The CFD study with existing chamber dimensions was carried out for the winter (Fig. 13) and summer seasons (Fig. 14). Keeping the ice bank top plate surface temperature constant at 0°C. The steady-state was achieved in 20 h and 27 h. Based on this, it was decided to reduce the chamber length from chamber bottom to front door bottom. The chamber capacity now is 50 L. Also, a fan is provided inside to circulate air and reduce the time taken for cooling.

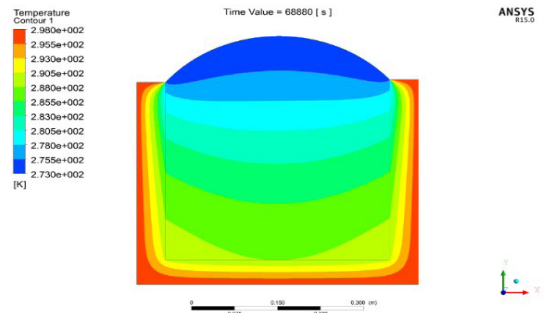


Fig. 13 CFD simulation of existing refrigerator chamber for the winter season

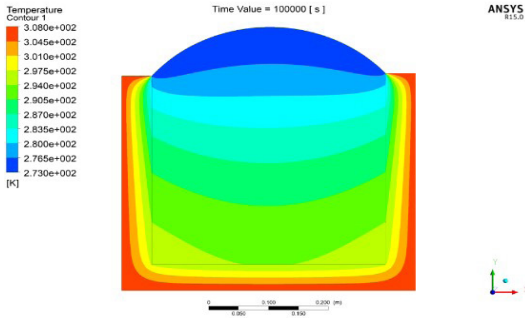


Fig. 14 CFD simulation of existing refrigerator chamber for the summer season

A double-capacity DC compressor along with related components like condenser and fans were introduced.

- The modified system was first tested on the grid (12 h supply; 08:00 am to 08:00 pm) for five continuous days. The chamber bottom temperature reached 8 °C in 6.5 hrs (Fig. 15). The duration includes the charging time of the ice bank also.

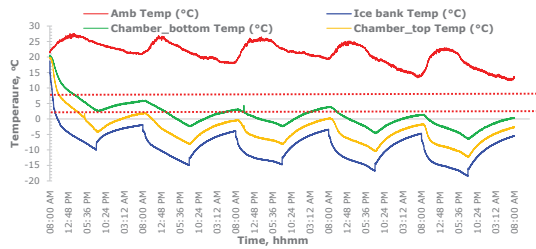


Fig. 15 Temperature profile on grid supply (12 h operation)

- During the load test with 5L water placed in a cold chamber, using a thermostat set at 5 °C and 6 hrs of compressor operation cycle on grid supply, the temperature of the load was observed maintained within the 2 to 8 °C range (Fig. 16) after the charging period as required for vaccine storage. The power consumption of the DC compressor was observed at ~ 100 W/h.
- As the test was successful on the grid, the system supply is shifted to a 150 Wp panel

with electrical battery backup. Further testing is in progress.

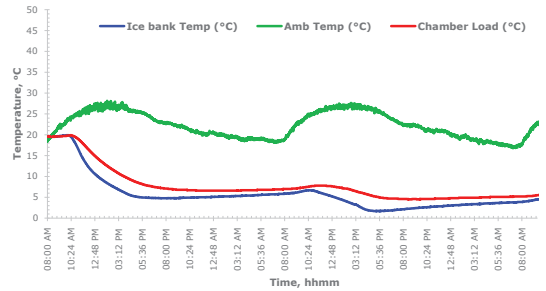


Fig. 16 Temperature profile on grid supply (6 h operation; with thermostat)

On-farm demonstration and performance analysis of an off-grid renewable energy-driven cold storage (Bilateral Indo-Danish DST project)

- The Danish partner was informed about the identified sub-zero temperature adsorption chiller in March 2021 for adapting it in place of the absorption-based configuration finalized earlier.
- During April & May 2021, internal meetings with the Danish team was held to discuss the type of chiller selection based on technical and recent costing data. Brief information on the comparison of identified chillers is given in Fig. 17. The matter was discussed with AAU, Denmark, and in both side's Steering Committee Meetings (SCM) meetings, and approval was taken to go for the adsorption chiller.
- A progress report was mutually prepared with AAU, Denmark and submitted to DST. The progress was found satisfactory and therefore budget revalidation was received for FY 2021-22.
- A final attempt to identify a suitable user was made by advertising a call of interest, in three local newspapers. A total of 11 farmers contacted SPRERI and made

inquiries. Among them, 2 farmers agreed to further discussion. Their sites were visited during August 2021.

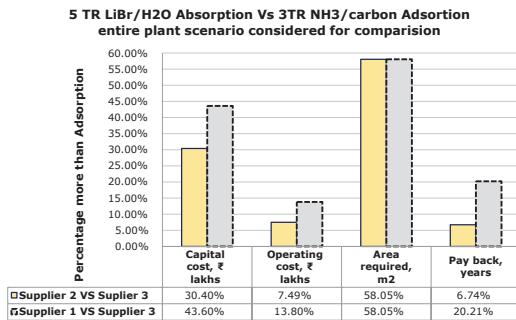


Fig. 17 Scenario comparison of supplier-1 and supplier-2 absorption chiller-based plant with supplier-3 adsorption chiller-based plant

- No genuine farmer was identified. So, it was decided to install the system at SPRERI premises, which was already agreed to by DST, Dr. Ahmad Arabkoohsar (PI, Denmark partner), and both Steering Committees.
- The purchase procedure was initiated, and the vendors were subsequently finalized for chiller and cold room supply. Solar thermal system suppliers' technical proposal evaluation is in progress.
- SPRERI has also carried out civil work i.e. ground leveling, and RCC platform construction for the installation of the system.
- On January 13, 2022, PAC meeting of DST was held, wherein the project progress was presented and a request for project extension till March 31, 2023, was sought.
- On March 25, 2022 comments of the PAC meeting were received where the project was asked for a short closure. Justification against the comments were submitted to DST.
- For the simulation study of the above and underground cold rooms, average soil

temperatures at the surface and depths close to the surface up to 4.5 m were determined, considering weather data and type of soil for Anand, Gujarat. It was observed that for 4.5 m depth the change in temperature around the year is a maximum of 2.3 °C and for the surface, the same is 12 °C (Fig. 18). So, for Anand city, the underground cold room will have less heat gain.

- The TRNSYS model for the underground and above-ground cold room was made with applicable weather conditions for Anand, Gujarat. A complete plant model (Fig. 19) has also been developed and its refining is in progress.

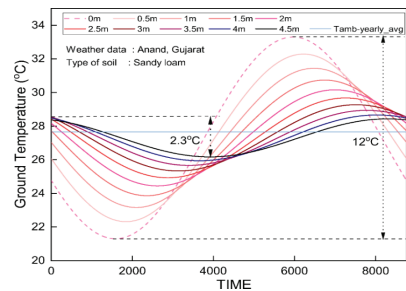


Fig. 18 Temperature variations for a year at different underground depths

1.5 Nano-materials in solar applications

Comparative analysis of heat transfer fluid with soot particles of diesel engine and waste engine oil in solar thermal systems

Stability of prepared soot particles based nanofluid

In the case of nanofluids with 0.1 and 0.2% w/w soot particles with and without surfactant and for different pH, the stability was observed good even after 240 days. Fig. 20 shows the stability of nanofluid with DI water and soot particle for 0.5% w/w with different variations of surfactant and sonication time. With 2 h of sonication, prepared nanofluid is unstable after 15 days and 60 days with and without surfactant. While, for 4 h sonication nanofluid

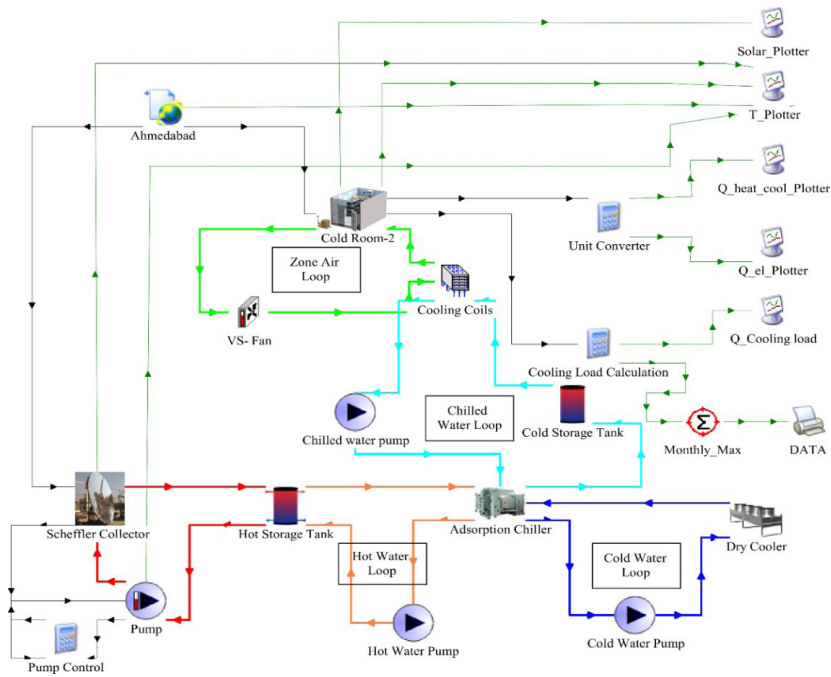


Fig. 19 TRNSYS model of cold storage with adsorption chiller

is unstable for the acidic condition with 0.02%, 0.05% w/w surfactant, and without surfactant. It is observed that as the pH of the nanofluid is increased, it shows better stability.

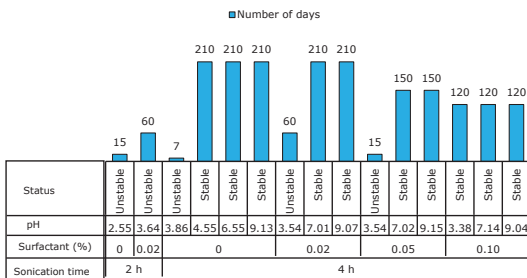


Fig. 20 Nanofluid with 0.5 % of soot particles and DI water

In general, from the study, it is observed that the stability of nano-fluids varies with soot particle concentration, sonication time, % w/w surfactant added, and variation of pH. Prepared nanofluids show very good absorption of light in the range of 190 nm to 1100 nm wavelength.

Performance analysis of solar thermal collectors

Comparative performance analysis of solar collectors has been done with and without

nanofluid. Direct absorption mode (**DAM**) base-collector (0.5 m²) was tested with nano-fluid and heat transfer mode (**HTM**) type conventional collector (0.5 m²) without nanofluid. The nanofluid used was of soot particle concentration 0.1% w/w without surfactant & given sonication. Table 8 shows that as the flow rate increases, efficiency of the both collectors decreases. The % improvement in thermal efficiency was observed to be at 14.7 to 18.7 higher than a conventional collector.

Table 8 Efficiency of the solar thermal collector with and without nanofluid at different flow rates

S.N.	Avg. flow rate	Avg. efficiency (%)		% Improvement in efficiency of collector with nanofluid
		Direct absorption mode (DAM) collector with nanofluid	Flat plate collector without nanofluid (HTM)	
1	36 LPH	70.8	59.7	18.7
2	46 LPH	66.5	58.0	14.7

2.1 Bio-methanol: The next generation bio-fuel from methane by methanotrophs

Methane is a toxic greenhouse gas which is generated from dumping grounds, landfills, oil and natural gas systems, agricultural activities, coal mining, stationary and mobile combustion, wastewater treatment, and certain industrial process. Mitigation of methane to useful products like methanol would not only lead to energy generation but also reduce the toxic effect of methane on environment. Use of natural biological catalysts for conversion of methane to methanol is a sustainable process. The study was successful in isolation of methylotrophic bacteria from cowdung slurry and paddy soil which used both methanol and methane as sole carbon source for their growth. The isolated strains were identified as *Methylobacillus flagellatus*, *Plastorhodobacter daqingensis*, *Halomonas lactosivorans* and *Zobellella denitrificans*. This study was initially carried out in 100 mL serum bottles which was further scaled up to a 3 L reactor (30x). Among all the strains, *Methylobacillus flagellatus*

showed highest methanol yield from methane which was found to be around 2.7 mM.

2.2 Lipid extracted micro-algae biomass residues (LMBR) to bio-hydrogen and aquafeed

In this study, LMBR was pre-treated with various alkali and acids to release carbohydrates or sugars for hydrogen fermentation. The highest value of COD was obtained with 1% NaOH treatment with 1 h autoclave as 118.5 g/L which was 73% higher than the test carried out with 1% NaOH for 12 h at room temperature. The pre-treated slurry of LMBR generated maximum hydrogen content of 40.2% v/v at 37°C when the mixture of dairy sludge and rice straw compost were used as inoculum. This study was further extended by supplementing enzymatic hydrolysate of algae biomass to the above fermentation mixture of LMBR in order to increase the total available sugars for hydrogen production. This resulted in further enhancement of H₂ yield upto 59% v/v and 30-35 mL/g LMBR. Metagenomic analysis of the fermentation sample revealed the prevalence of Bacillus and Clostridia genus bacteria

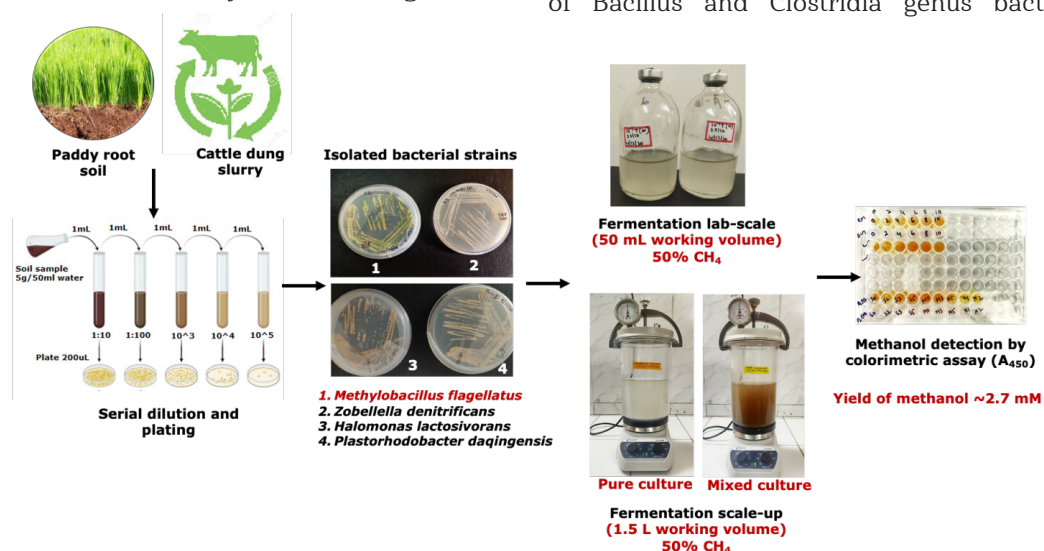


Fig. 21 Bio-methanol studies using *Methylobacillus flagellatus*

which are reported to be hydrogen producing bacteria. Elemental and CHN analysis of LMBR further corroborated its potential to be used as aquafeed. The potential of LMBR as fish feed was evaluated by conducting experiments on freshwater fish (*Common carp*). An increase in body weight of upto 30% was observed by using LMBR as the sole feed in comparison to 45% increase in weight while using commercial feed. This concludes that LMBR which is otherwise a waste can add value to the micro-algae biorefinery by its bio-conversion to hydrogen and aquafeed, thereby justifying the concept of zero waste or circular bio-economy.

2.3 Ex-situ treatment of rice straw using novel microbial consortia

Rice straw (RS) decomposition is an attractive solution to open-field burning but the traditional method of decomposition has slow

kinetics and takes longer time (60-90 days) to get a mature compost. In this study, we propose to boost up the decomposition process by addition of a novel microbial consortium rich in lignocellulolytic microbes. Maximum degradation of rice straw was observed in the thermophilic phase as indicated by the decrease in C:N ratio and increase in degradation efficiency of cellulose and hemicellulose. C:N ratio of the compost reached a value of 14.62% on 25th day which is a clear indication of a mature compost. Degradation efficiency of 70% and 93.61% was obtained for cellulose and hemicellulose respectively within 20 days. Lignocellulolytic activity of the microbial consortium was confirmed by plate and activity assay. Activity of endoglucanase and xylanase was found to be 2.8 U/g and 3.4 U/g, respectively on the 15th day of composting. Further, 16S rRNA metagenomic analysis was carried out to study

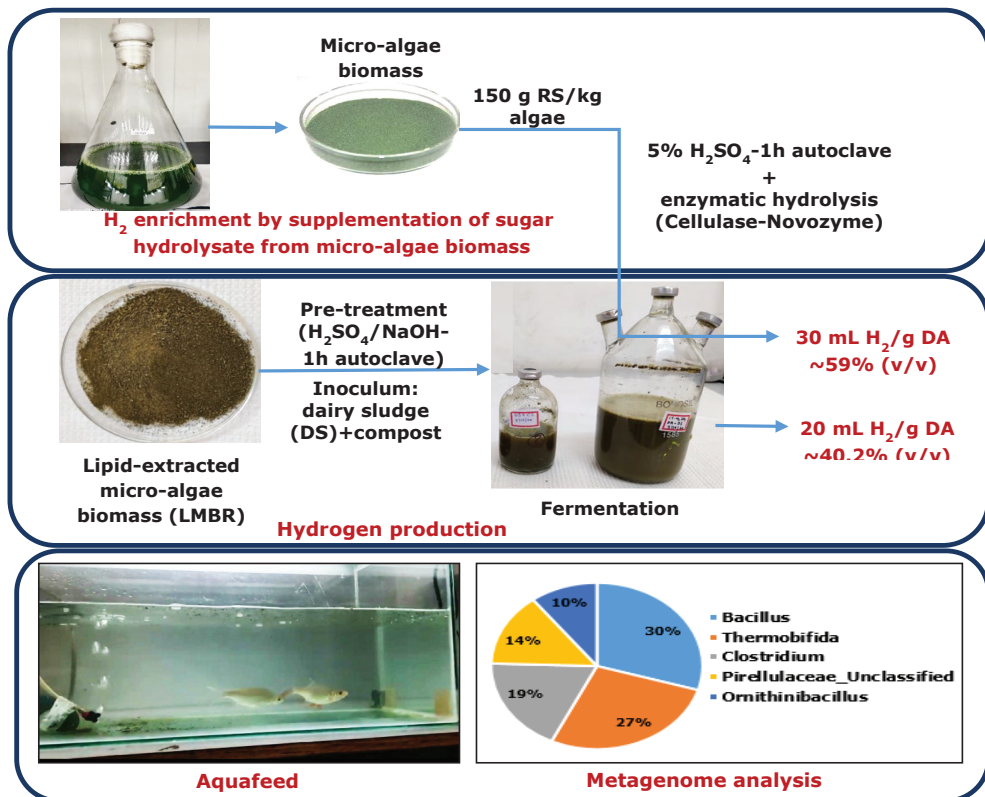


Fig. 22 LMBR to bio-hydrogen and aquafeed

stabilized in the presence of air while the second step of carbonization took place in the presence of nitrogen. Under stabilization, the nanofibers were heated upto 100°C at constant rate of 0.5°C/min and kept at that temperature for 1 h. Then, temperature was increased to 180°C at a constant rate of 0.5°C/min. Nanofibers were held at 180°C for 16 h, followed by heating at 250°C at 0.5°C/min rate and retention at this temperature for 8 h. The fibers were then naturally cooled to room temperature before undergoing carbonization. The stabilization step is necessary as it helps in the formation of cross-linked structures between carbonyl and carboxyl groups, which prevents the melting of fibers during carbonization. Under the carbonization step, fibers obtained from stabilization step were carbonized at different temperatures for optimization (600, 900 and 1200°C) at a rate of 3°C/min under constant supply of nitrogen and cooled to room temperature under nitrogen atmosphere.

2.5 Evolving a model on scientific management of wet waste for a small town

In small towns, unsegregated garbage or waste is generally dumped by residents, restaurants, eateries, institutions, vegetable shops, etc on the road side, drains, water bodies or garbage bins placed across the town. The Municipality or Nagarpalika, depending on the population of the town arranges to empty the garbage bins at regular intervals and transports the waste to a dumping site outside the town. This is clearly not a process that should continue. Land for dumping sites is also not always available and a more environmentally appropriate solution is required.

Given the fact that the Government is giving importance to solid waste management as it is a growing burning issue, a survey was conducted by SPRERI in Karamsad, Vidyanagar, and Anand covering about 270 to 300 hotels, eateries and mandi yards. It was

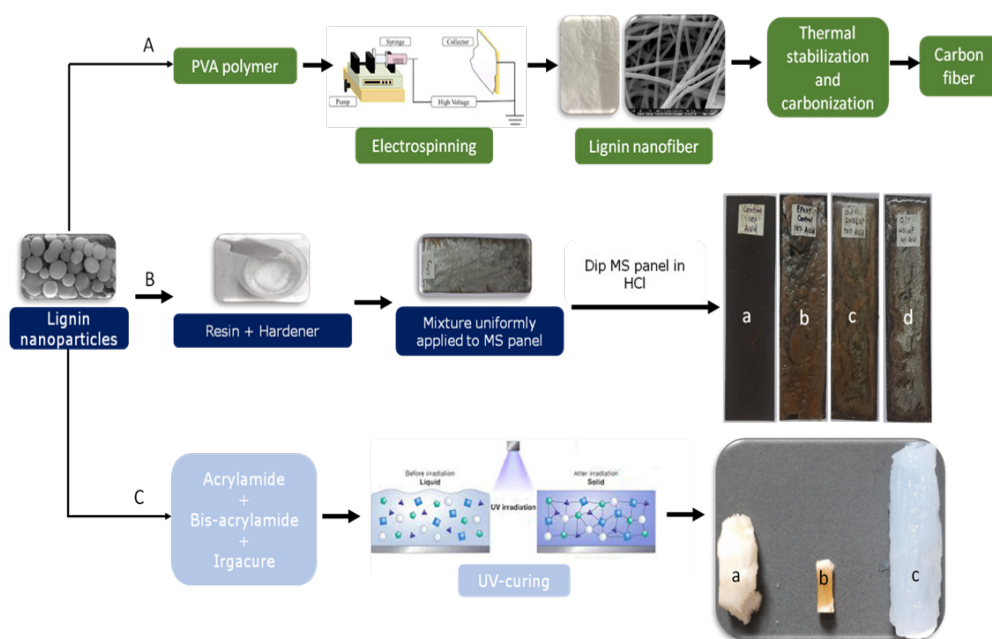


Fig. 24 Valorization of lignin for different applications: A) Lignin nano-particles into nano-fibers and carbon fiber, B) Lignin nano-particles for anti-corrosion application: a. Without coating b. Epoxy control c. Indulin nano-particle coated d. Lignin nano-particle coated C) Lignin nano-particles into nano-gel: a. nano-gel b. dried nano-gel c. water absorbed nano-gel

found that approximately 2 tonnes of kitchen waste is being generated per day from these eateries. Vallabh Vidyanagar does not have a dumping site and unsegregated garbage from Vallabh Vidyanagar is being transported to the neighbouring Anand dumping site. With growing population and waste generation, it is evident that both the towns cannot sustain this current practice of waste disposal over a long term. The matter was taken up with the Nagarpalikas and an MoU was signed with them to work together to scientifically manage the wet waste from these eateries. SPRERI has also signed an MoU with Shree Krishna Hospital (a charitable hospital) in Karamsad for implementation of the project at the site to be provided by them. In return the biogas generated in the plant will be used in the kitchens of the hospital and hostels of the Medical College and Hospital. This is expected to replace around 150 cum/d of PNG. The expected generation of the bio-fertilizer is ~ 0.5 T/d to be sold to farmers in the area at a subsidized price.

The waste-to-energy plant installed by **SPRERI** based on its own **Patented odourless technology** has been funded by the Department of Biotechnology, Government of India under their clean energy scheme and was launched officially by Dr. Renu Swarup, Ex-Secretary, Department Bio-technology, New Delhi on 1st October 2020 to mark 152nd birth anniversary of Mahatma Gandhi. Apart from the scientific treatment of the waste through SPRERI's patented bio-methanation technology, the project expects to focus on bringing behavioural changes in the commercial establishment (hotel, eateries, restaurant and roadside dhaba) owners about segregation of wet organic waste from the mixed waste generated by them. **This is first**

such initiative in Anand, Vallabh Vidyanagar and Karamsad towns of Gujarat.

Currently SPRERI team has covered around 200 establishments in Vallabh Vidyanagar and Karamsad Nagarpalika and is creating an awareness on segregation of wet waste, its collection and transportation with the help of Centre for Applied Research and People's Engagement (CARPE), Aurangabad. CARPE is a social enterprise working in the area of solid waste management. They conducted events to bring about awareness on segregation at source and non-dumping. After creating awareness, substantial change is seen in 90% of the establishments. At full capacity, the project is expected to reduce the burden of 1277.5 Tons of waste per annum in the landfills, and is expected to reduce the carbon footprint @ 0.66T CO₂/T waste/ year. Moreover, the biogas produced will reduce the carbon footprint by 3.024 T CO₂/T waste/year by replacing PNG.

M/s. GMM Pfaudler, Karamsad has provided a garbage tipper for the collection of the segregated wet waste by SPRERI. This was considered necessary to streamline the process of collection of segregated wet waste and delivery to the plant site. Moreover, this will facilitate monitoring and fixing accountability and the experience gained will be useful for training the Nagarpalika staff later, who will be expected to take over post commissioning with technical back-up support from SPRERI. Vallabh Vidyanagar Nagarpalika has provided a separate vehicle for this project to cover the Vallabh Vidyanagar establishments. Currently, the segregated wet fraction of 1.5 TPD and remaining 1.0 TPD vegetable & fruit waste from mandis is being transported to the bio-methanation plant site by SPRERI which is getting converted into bio-gas & bio-fertilizer. Performance monitoring of the plant is in progress.

3.1 Gasification

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

The team has conducted an energy audit to capture pre-commissioning fuel (sawdust) consumption data for both the targeted applications; i.e., hot air generator and hot water tank at *New Raj Food Industry (NRFI), Dahod*, and found that a 100 kg/hr capacity fluidized bed gasification system is needed to meet the thermal requirements. Based on preliminary data, 100 kg/hr (i.e. 4,00,000 kcal/hr) SPRERI-TECH FBG system was installed for the targeted applications of the industry.

Initially, the trial runs on the hot air generator using the gasification system were conducted at no-load condition for the dryer to overcome the risk of low-quality products. During the trial, the air was heated up to the required stable temperature range (200-250°C) for the drying application and was operated for 3 hours and 20 minutes at an average feeding rate of ~105 kg/hr (Table 9). The overall fuel and fuel cost savings will be worked out after completion of successful long-duration trials during the actual production cycle. The system is yet to be commissioned. The delay is due

to the shortage of fuel and induction of new operators to run the complete process.

Identification of other beneficiaries

The TCC team has started to look for other beneficiaries under the scope of the project and has started visiting poha-making units in Ahmedabad, Dahod, Godhra, Panchmahal and Anand districts.

3.2 Pyrolysis

The continuous pilot-scale intermediate pyrolysis system

The feasibility trials on the SPRERI-Tech pilot-scale continuous pyrolysis system were completed successfully along with the attachment of the cyclone burner into the combustion chamber for pyro-gas combustion for in-situ utilization of pyro-gas (Fig. 25). Followed by the burner stabilization, the pilot-scale continuous pyrolysis system was optimized. For this purpose, the material feeding rate was optimized (~11 kg/hr) for thermal stability. Two sets of trials (without and with in-situ utilization of pyro-gas) were completed successfully for sawdust as a feedstock. First, the trials without in-situ utilization of the pyro-gas were completed to evaluate the LPG consumption for the process (Table 10). Afterwards, trials with in-situ

Table 9 Comparison of the trial runs of the FBG system with the previously recorded average values

S.No.	Parameter	Avg. values obtained during open firing of sawdust	Values obtained with gasification of sawdust
1.	Average air flowrate (m ³ /hr)	3,000	3,000
2.	Avg. air inlet temperature (°C)	27.15	31.00
3.	Avg. air outlet temperature (°C)	170.19	198.57
4.	Max. air outlet temperature (°C)	240.00	250.00
5.	Total duration (hh:mm)	07:41	03:20
6.	Sawdust feeding rate (kg/hr)	160.74	105.30

utilization of pyro-gas were carried out at the same process parameters (Feeding rate: ~11 kg/hr and Process temperature: $475 \pm 5^\circ\text{C}$). During these trials also, an exact LPG consumption pattern was recorded for the feeding cycle of the process (Table 11).

From the data, it can be seen that with no change in the average product yields of bio-char, bio-oil and pyro-gas, the specific fuel consumption (SFC) has been improved by ~40 %. With the reduction of LPG consumption, the operational cost is expected to decrease substantially and it will eventually lead to a reduction in the production cost of the bio-

oil & bio-char. The detailed techno-economic analysis will be carried out at the end of the complete study with other feedstocks. At present, further experimental trials using cotton stalk as a feedstock are in progress.

Fast pyrolysis

In the previous year's annual report, the design parameters of the fast pyrolysis system and bio-oil yield in the catalytic and non-catalytic modes were discussed. Furthermore, the characterization of the generated products (bio-oil & biochar) from the fast pyrolysis of SD, GNS and CS (catalytic and non-catalytic

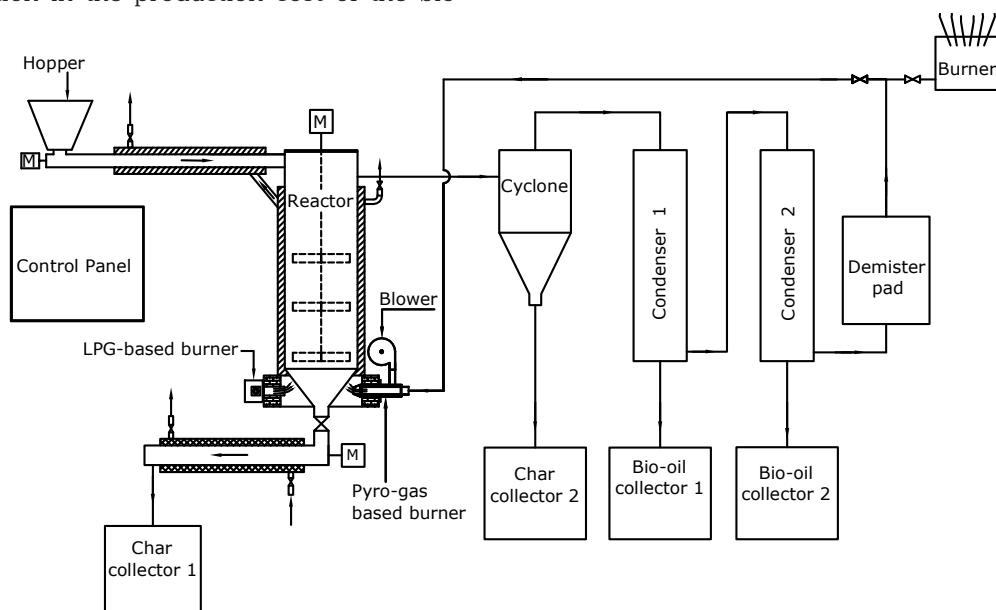


Fig. 25 Schematic arrangement of in-situ utilization of pyro-gas

Table 10 Data on (with and without in-situ utilization of pyro-gas) in a pilot-scale continuous pyrolysis system

S. No.	Feedstock	Process temperature ($^\circ\text{C}$)	Set of trial	Material feeding rate (kg/hr)	Avg. product yield (wt. %)			LPG consumption rate (kg/hr)	SFC (kg LPG per kg Sawdust)	LPG saving (%)
					Bio-char	Bio-oil	Pyro-gas			
1.	Sawdust	475 ± 5	1 st	11.39	23.38	42.64	33.98	2.27	0.20	41.41
			2 nd	11.26	25.25	39.76	34.99	1.33	0.12	

1st set of trials: Without in-situ utilization of pyro-gas

2nd set of trials: With in-situ utilization of pyro-gas

mode) was done to evaluate the quality of the bio-oil.

Bio-oil characterization

The physical properties such as pH, solid content and calorific value of the bio-oil are presented in Table 11. Due to the decrease in the oxygenated compound in the catalytic bio-oil, the organic content and the properties of the bio-oil are enhanced in comparison to the

non-catalytic bio-oil. It can be shown from Table 11, due to the decrease in the oxygenated compounds in catalytic bio-oil, the acidic nature (4.11-5.75) and solid content (2.87 - 7.84 wt. %) decreased in comparison to the pH (3.12-4.05) and solid content (4.23 - 8.22 wt. %) of non-catalytic bio-oil. Due to the increase in the organic fractions, the calorific value of the catalytic bio-oil increased by ~2-3 MJ/kg in comparison to the non-catalytic bio-oil.

Table 11 pH, solid content and calorific value of bio-oil obtained from fast pyrolysis of sawdust (SD), groundnut shell (GNS) and cotton stalk (CS) in catalytic and non-catalytic mode

Bio-oil	pH	Solid content (wt. %)	Calorific value (MJ/kg)
SD (non-catalytic)	3.12	4.23	27.31
SD (Fe ₂ O ₃)	4.30	3.60	28.57
SD (CaO)	4.29	3.31	28.01
SD (MgO)	4.17	3.11	27.79
SD (TiO ₂)	4.13	2.87	27.50
GNS (non-catalytic)	4.05	5.57	29.89
GNS (Fe ₂ O ₃)	5.75	4.13	31.41
GNS (CaO)	5.18	4.01	30.86
GNS (MgO)	4.75	3.88	29.95
GNS (TiO ₂)	4.86	3.98	29.91
CS (non-catalytic)	3.32	8.22	28.87
CS (Fe ₂ O ₃)	4.45	7.84	30.28
CS (CaO)	4.11	7.21	29.96

Bio-char characterization

Table 12 Proximate analysis, calorific value and bulk density of the bio-char produced from fast pyrolysis of sawdust, GNS, and CS in non-catalytic mode

Bio-char obtained from	Proximate analysis				Calorific value (MJ/kg)	Bulk density (kg/m ³)
	Moisture content (wt. %)	Ash content (wt. %)	Volatile matter (wt. %)	Fixed carbon (wt. %)		
SD	5.67	31.46	30.17	32.70	28.08	300
GNS	4.71	33.23	28.88	33.18	27.76	292
CS	3.89	34.21	29.65	32.25	27.53	265

Characterization of the bio-char obtained from fast pyrolysis of sawdust, GNS and cotton stalk was done (Table 12). The calorific values of the bio-char observed are in the range of 27-28 MJ/kg. As the air was used as a fluidizing medium, a higher ash content (31-35 wt. %) was observed in the bio-char.

3.3 Combustion

Gasification vs combustion: Comparison of a fluidized bed gasifier and a pellet burner

The detailed comparison on gasification with combustion was made in this study by keeping 1,00,000 kcal/h as heat output. The division therefore used a pilot-scale fluidized-bed gasification (FBG) unit and a pellet burner. The performance of a FBG unit and a pellet burner was examined with a combustion chamber at no-load conditions. The emission profiles including the particulate matters (PM >1.6 µm) associated with the gasification of sawdust and combustion of sawdust pellets were measured. During this, both units were operated (at their respective optimized parameters) to meet the

heat duty of 1,00,000 kcal/h. The arrangements of both fuel-processing units during the process are as depicted in Fig. 26.

For 1,00,000 kcal/h heat delivery, FBG and pellet burner were operated with 36 kg/h (sawdust-loose form) and 25.50 kg/h (sawdust-pelletized) feed rate, respectively and emission profile with flame temperature data were recorded and are given in Table 13.

The SPRERI-Tech FBG shows lower emission in comparison with a commercial pellet burner. The liberation of particulates during combustion of producer gas attached with gas cleaning systems (in case of FBG) is nil, while 1 g/m³ of particulates liberation was recorded with a commercial pellet burner.

In order to arrive at the total operation cost, the major cost associated parameters (i.e. raw material, electrical, and manpower) were recorded during the trials. On the basis of these parameters, the cost (i.e. operational and maintenance cost) for both the processes was calculated. With the data obtained, it is seen

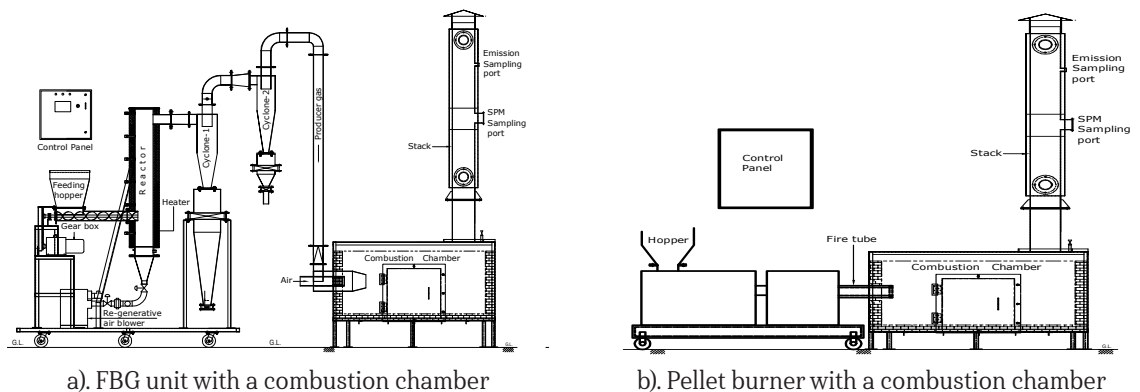


Fig. 26 Emission measurement set-up

Table 13 Emission profile of both systems

	O ₂	CO	NO _x	CO ₂	PM	Flame temperature	Flame Length
	vol. %	ppm	ppm	vol. %	g/m ³	°C	feet
FBG	6.74	93.22	78.11	15.32	0.0	750	4.00
Pellet burner	9.70	190.84	215.38	11.54	1	1050	3.50

that the total operation & maintenance cost of FBG is ~45 % lower than the pellet burner for 1, 00,000 kcal/hr heat output (Table 14).

Table 14 Cost analysis of both fuel processing technologies for a 1, 00,000 kcal/hr capacity system

S. No.	Description	Pellet burner	FBG
1.	Total operational and maintenance cost	476.24	262.08 ₹/h
2.	Net saving offered by a FBG unit compared to a pellet burner	N/A	214.16 ₹/h
			1,713.29 ₹/shift
			5,13,987.25 ₹/annum

Though, the FBG unit required greater capital investment (64% higher than a pellet burner), it offers 45% lesser operation cost year on year (Table 14). Further, the revenue saving achieved with an FBG unit inclusion for the said heat duty results in a payback time of ~10 months. In compliance with the explained techno-economic comparison of both the fuel-processing technologies, the benefits offered by an FBG unit were found acceptable.

3.4 Value-added products from agro-residues

Production of activated carbon from different agro-residues and bio-char of the different agro-residues

The pilot-scale system was fabricated and successfully installed at the Institute (Fig. 27). Subsequently, the system was tested for

Table 15 Product yield MB_n and cost of different activated carbon samples

S. No.	Activated carbon	Product yield (wt.%)	MB _n (lab-grade) (mg/g)	MB _n (Industrial-grade) (mg/g)	Cost with lab-grade (Rs/kg)	Cost with industrial-grade (Rs/kg)
1.	AC_GNS char_ZnCl ₂	~87	198.1	197.2	1486	290
2.	AC_GNS char_KOH	~89	170.5	165.2	15646	214
3.	AC_GNS char_H ₃ PO ₄	~81	130.0	126.0	1010	208

cold trials and pyrolysis experiments before starting the chemical activation trials.



Fig. 27 Image of the installed pilot-scale (5 kg) reactor for the production of activated carbon from bio-char of agro-residues

The chemical activation trials on a pilot-scale activated carbon reactor system were started with the activation of groundnut shell pyro-char. The pyro-char was generated using SPRERI-Tech pilot-scale continuous pyrolysis system (pyrolysis temperature: 450°C). The produced char was screened and fed into the reactor (5 kg) via feeding hopper followed by activating agent ZnCl₂, KOH and H₃PO₄ (1:1 impregnation ratio) and DI water (20 litres). For the experiments in the pilot-scale system, industrial-grade activating agents were used.

The product yield (wt. %) for the final activated product was observed to be in the range of 87-90 wt. % for the selected feedstock (Table 15). The in-house characterization of the activated carbon (MB_n) was carried out simultaneously. The samples for BET, SEM and EDX analysis are in progress.

The cost calculation was done for the production of activated carbon from lab-grade and industrial-grade activating agents (Table 15). It was observed from Table 15, the cost of activated carbon is in the range of Rs 200-300 /kg which is cheaper than the cost of production of activated carbon with lab-grade activating agents (Rs. 1000-16000/kg).

Production, characterization and demonstration of char pellets as a fuel in

forced-draft cookstove

To assess the char pellets' performance as a fuel, combustion test was carried out for each pellet type in the forced-draft cookstove, where its thermal efficiency and emission profiles were recorded (Table 16). The measurement of thermal efficiency and emission profile was done following the norms of the Bureau of Indian Standard (BIS) for cookstove testing.

Table 16 Thermal efficiency and power output of cookstove with char pellets

S. No.	Description	CV (MJ/Kg)	Burning rate (Kg/h)	Thermal Efficiency ($\%, \eta_{th}$)	Power Output (KWth)
1.	Sawdust char + Banana Stems 20%	22.45	1.45	37.54	3.40
2.	Sawdust char + sugarcane Bagasse 20%	22.72	1.96	32.24	3.98
3.	Sawdust char + Tea Waste 20%	23.29	1.61	37.42	3.89
4.	Sawdust char + Starch 10%	21.37	1.41	36.13	3.02
5.	Sawdust char + Potato peels 15%	23.50	1.61	35.34	3.71
6.	Groundnut shell char + Banana Stems 15%	22.78	1.53	38.23	3.69
7.	Groundnut shell char + Sugarcane Bagasse 20%	21.06	1.61	33.37	3.14
8.	Groundnut shell char + Tea Waste 20%	22.57	1.64	38.57	3.96
9.	Groundnut shell char + Starch 10%	22.89	1.55	37.45	3.69
10.	Groundnut shell char + Potato peel 20%	21.75	1.58	38.06	3.63
11.	Wood charcoal - chunks	26.85	1.43	32.19	3.43

The efficiency test was done based on water-boiling tests, as described by BIS. Overall, it was found that all types of char pellets have exhibited good combustion behaviour in comparison with wood charcoal chunks. The study has suggested the use of various other biomasses which can be used as blends in pellet making followed by its conversion to char & its usage in forced-draft cookstoves.

Training and Awareness Creation

Training and Demonstrations

The division continues to raise awareness about renewable energy resources and technologies in rural areas, educational institutions, and various non-governmental organizations. SPRERI organized a visit for students to SPRERI. Details are shown below:

- 55 students of St. Stephen Institute of Business Management and Technology Industrial Training Institute (ITI), Anand visited on 20.10.2021
- 35 students of Diploma Mechanical Engineering from Parul Institute of Engineering and Technology, Parul University, Vadodara visited on 29.10.2021.
- 55 students of Industrial Training Institute (ITI), Vallabh Vidyanagar visited on 25.03.2022.



Fig 28 Students visit at SPRERI

Technology and Machinery Demonstration Mela

Based on ICAR guidelines, SPRERI organized Technology and Machinery Demonstration

Mela on 25th March 2022. The purpose was to create awareness about different renewable energy technologies and machineries mainly for Farmers. The scientists and technical staff of SPRERI explained the technologies and interacted with the participants. 35 students of CVM Technology Industrial Training Institute(ITI), Vallabh Vidyanagar, 18 students of P. D. Patel Institute of Applied Sciences, Charusat University Changa and 110 Farmer and SHG Women visited SPRERI during the Mela.



Fig 29 Farmers visited SPRERI during the Mela

National Campaign on Farm Mechanization Programme

Under ICAR's National Campaign on Farm Mechanization Programme, the Extension division organized an awareness programme at Daloli, Bhalada, Shekhupur and Matar villages of Kheda District on Renewable energy technologies. 55 farmers participated in the programme.



Fig 30 National Campaign on Farm Mechanization Programme at Matar and Daloli village

Training organized

One week training on “Solar Energy Utilization” organized on 27th Sep. to 1st Oct. 2021

The One-week training program on “Solar Energy Utilization” was organized by the Solar Energy Division, from 27th Sep. to 1st Oct. 2021. Twenty five participants attended the training. The main objective was to impart knowledge to participants on solar technologies, PV system designing, and provide hands-on training.

The programme consisted of a well-planned series of lectures explaining the working of all these components and their selection criteria. The sizing of each component using basic governing equations and using System Advisor Model (SAM) software was explained to the participants. The solar energy policies and latest advancements in solar thermal and photovoltaics were also discussed in this training.

Feedback received was that, SPRERI should organize such training in physical mode for one week, wherein participants’ enthusiasm for learning can be fully served with hand-on sessions.

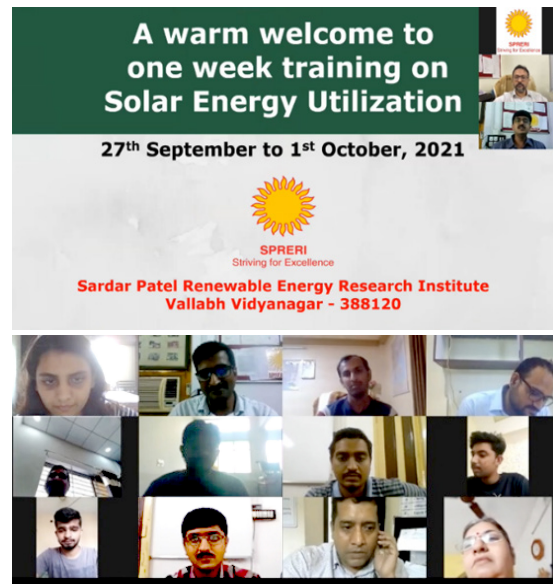


Fig. 31 One-week online training

Technology Demonstrations

4.1 DST Core Support Programme

For implementation of a **walk-in type solar tunnel dryer**, SPRERI's team surveyed and collected base data from various sites of Kheda, Anand and Chotta Udepur districts for identification of potential beneficiaries/ community group for initially income generation activities or creation of entrepreneurship development in their respective area / farms. A tunnel like framed structure covered with UV-stabilizer polythene sheet for bulk drying of agricultural products at moderate air temperature was developed and farmers from Isnava village have shown an interest in setting up a solar tunnel dryer. Capacity finalization, design and detailed drawing with cost was prepared for drying *jalbrahmi* (*Bacopa monnieri*) crop as a medicinal product. The walk-in type solar tunnel dryer was installed on 21.01.2022 at Mr. Vimalbhai Patel farm, Isnava village, Anand district. The data collection on open sun and solar drying of *jalbrahmi* is in progress.



Fig 32 Solar walk-in type dryer installation and drying of jalbrahmi

38 students from College of Horticulture, Anand Agricultural University, Anand visited the solar walk-in type dryer and solid state biogas plant installed at Mr. Vimalbhai Patel's farm on 26.02.2022.

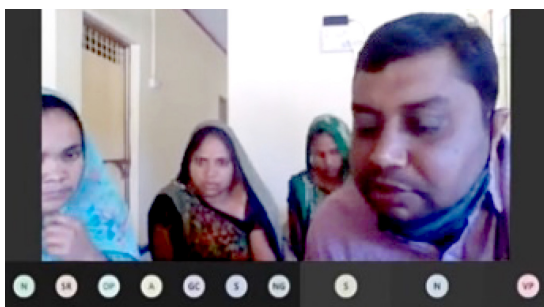


Fig 33 Discussion with students

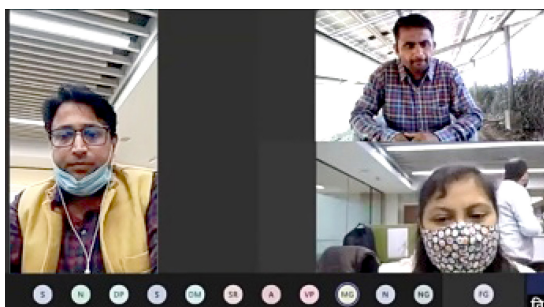
4.2 Participation in Techनीव@75

As the nation celebrates Azadi Ka Amrit Mahotsav, the SEED Division of Department of Science & Technology (DST) has taken the initiative “Techनीव@75. The main focus of the programme is to highlight the reach and impact of the S&T-led interventions among the communities in consonance with the spirit of Aatmanirbhar Bharat. SPRERI participated in Techनीव@75 programme on 11th February 2022 under the Theme: Energy Access for a Prosperous Society with SPRERITECH technologies beneficiaries. Under three sessions, the participants are as below:

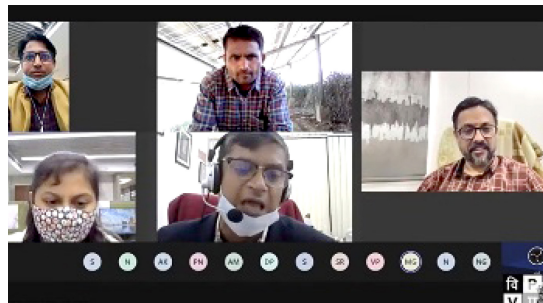
1. Mr. Paresh Mer and Maruti Missan Mangalam Group, Chotta Udaipur, Gujarat (*Community feedback and experience sharing*)
2. Er. Samir Vahora and Mr. Vimalbhai Kiritbhai Patel, Anand, Gujarat (*Discussing with the changemakers*)
3. Dr. Gaurav Mishra, Director (*Roundtable discussions*)



Community Feedback and Experience Sharing



Societal Changemakers' Conclave



Roundtable Discussion to Nurture and Strengthen Local Innovation

4.3 Dhabha-size biomass cookstove:

Demonstration of the forced-draft improved biomass cookstove (IBCS) were made at different small hotels or dhabhas, community-based cooking center and Nasta houses. During this year, 19 nos of demonstrations were conducted in different villages and 44 owners had participated. Eight Dhabha size IBCS were set up in Anand, Mahisagar and Chhota Udepur districts for initial demonstration. The base data of all the users has been collected for techno-economic evaluation. The pre and post implementation data for a hotel is shown below:

It was found that before the cookstove installation, the Kismat Kathiyawadi (Hotel), Borsad, Dist: Anand used to consume ~ 300 kg wood for rotla/rotli making and 28-30 LPG bottles per month for cooking various items. After installation of the IBCS the LPG consumption was found reduced to 20-21 LPG bottles.

The R S Gruh Udyog (Rice Papad making small-scale industry), Vasna, dist: Anand used to consume 85-90 kg fuelwood per day for 15 batches of papad making. After installation, the fuel wood consumption has been reduced by ~26% and ~25% time saving was made per batch.

Table 17 Pre-post data of dhabha size IBCS

Details	Pre implementation	Post implementation
Kismat Kathiyawadi Hotel		
Items prepared	Rice(4 kg), Dal (6 kg), Vegetable(12 kg), Gravy(25kg)	
Fuel used	LPG	Wood
Fuel consumption, kg	3	18.5
Price, Rs/kg	63	5
Total Cost, Rs	189	92.5
Annual saving, Rs		31,845
Time required for cooking, min	190	240
Excess time required for cooking, min		50

The Jay Ranchod Nasta House (Dhabha), Bhimpura Crossing, Dist. Vadodara used diesel stove and LPG. The Dhabha consumes around 6-7 liters diesel/day and 6-7 cylinder LPG per month. The performance monitoring is in progress.

40% less compared to the traditional stoves.



Fig. 34 Traditional and SPERITECH cookstove at R.S.Gruh Udyog Rice papad making industry

Fig. 35 Diesel stove and SPERITECH IBCS @ Jay Ranchod Nasta House, Bhimpura

reliminary feedback collected from users revealed that, the dhabha-size biomass cookstove is easy to use for continuous operation. The fuel requirement in the force-draft cookstove was found to be ~35-

4.4 Rural Development Programme

For faster dissemination of the SPERITECH technologies and/or products, demonstration-cum-awareness programmes were organized in **twenty-five** villages of two districts (Amrol, Ambhali, Bochasan, Rampara, Virsad, Borsad, Dabhan, Alindra chowkdi, Vahansol Chowkdi, Dakor-Bhalej road, Kanjari, Chikhodrachowkdi,

Khanpur, Devgadhi bariya, Petlad, Simarada, Dedarda, Singhrot, Bhimpura, Mota kalodara, Vastana, Matar and Vasna). Renewable energy technologies such as improved biomass cook stove, solid state biogas plant, and micro solar dome etc. were included in the programme. Around 104 male and 106 women took part in the demonstration programmes and actively interacted with the SPRERI staff.



Fig. 36 Construction of solid-state biogas plant at Ajarpura, Laljipura and Shardapura village

Family size **solid-state biogas plants** of 4 and 6 cum/d capacity have been constructed and commissioned at 4 selected farmer sites in

Ajarpura and Laljipura villages of Anand and Shardapura village Vadodara district (3 nos. 4 cum and 1 no 6 cum capacity). The biogas is being used for thermal application (cooking and water heating). Pre-installation data were collected for a socio-economic impact analysis.

4.5 Networking:

To create links with other organizations working in the same space in rural development for faster dissemination of the SPRERI technologies and/or products, SPRERI organised a two day exposure visit for a CARE India Dang team for Clean Cooking Energy and Household Air Pollution and its impact. Capacity Building Officer, Program Officer Clean energy and 8 community resource persons from Subir and Umarpada block of Dang and Surat districts participated in the exposure visit.



Fig. 37 Demonstration of IBCS and Micro solar dome at SPRERI during exposure visit and Tribal area of Dang during rural orientation programme

SPRERI also participated in a Community Rural Orientation programme organised by CARE India in Uga village, Subir taluka, Dang district and Morthan and Sevlan villages in Surat district. A total of 140 traditional cookstove user women participated in the orientation.

SPRERI organised a virtual meeting with Gujarat Livelihood Promotion Company Ltd. (GLPC), Sabarkantha district officials, 20 leaders from talukas and other team members participated in the meeting.



Fig. 38 Awareness and Demonstration of RE gadgets/devices at Tribal Research cum Training Center, Dahod

SPRERI team conducted an awareness-cum-demonstration program at the Tribal Research-cum-Training Center, Anand Agricultural University, Devgadhi Bariya, Dahod and five villages (Dolasan, Kanakiya, Gir Gadadha, Kesariya and Manodh) through Ambuja Cement Foundation (ACF), Kodinar at Gir Somnath district. Around 50 males and 167 females took part in the demonstration programmes and actively interacted with SPRERI staff.



Fig. 39 ACF KVK Demonstration Programme at Kodinar Gir Somnath

4.6 Field performance analysis of kitchen waste-based biogas plants set up in Anand district of Gujarat

To assess the field performance of kitchen waste-based biogas plants in Gujarat, a survey form was prepared in Kobo Toolbox to collect data on capacity, daily feeding quantity, gas generation and uses, feedback, observations etc. Data was collected from three biogas plants

Table 18 Kitchen waste-based biogas plants details

S.No.	Site of Biogas plant	Capacity	Installed by	Status
1	Swaminarayan Gurukul, Gadadha	60 kg/d	GEDA authorized contractor, 2017	Working
2	Plant-I Charutar Arogya Mandal, Karamsad	100 kg/d	SPRERI, 2019	Working
3	Plant – II Charutar Arogya Mandal, Karamsad	100 kg/d	SPRERI, 2019	Working
4	IRMA, Anand	150 kg/d	SPRERI, 2021	Working
5	NIRMA, Ahmedabad	250 kg/d	M/s Sahas, Vadodara, 2021	Working
6	Vatsaly International School, Borsad	50 kg/d	GEDA authorized contractor, 2021	Working
7	Santram Mandir, Karamsad	85 kg/d	M/s H. Haavi Engineering, 2021	Working

set up by SPRERI and four biogas plants set up by other agencies. Out of 7, five biogas plants are in working condition. In the case of two plants the user is adding cattle dung with kitchen waste due to non-availability of the substrate.

Results of the data collected for the 7 working plants have been summarized in Table 19.

The biogas at all the sites is being used for thermal application. The kitchen waste and water ratio were found to be 1:2 to 1:3. The methane content of the biogas samples collected from sites were found to be around 61-66% with an average 82-95 litre of biogas generated from 1 kg waste. The inlet pH of waste is around 6.4-6.7 and the outlet is 6.6-6.8.

The above data indicates that the biogas plants installed by SPRERI shows better performance compared to other plants.



Fig. 40 Biogas plant at Vatsalya International School, Borsad



Fig. 41 Biogas plant at IRMA, Anand

Table 19 Field performance of the kitchen waste-based biogas plants

Sr. No	Site of Biogas plant	Capacity, kg/d	Daily fed, kg/d	Biogas yield, cum/d	Biogas yield, l/kg
1	Swaminarayan Gurukul, Gadadha	60	10-12 KW + 48-50 Cattle dung	-	-
2	Plant – I Charutar Arogya Mandal, Karamsad	100	60	5.5-6	91-100
3	Plant – II Charutar Arogya Mandal, Karamsad	100	80	8-8.5	100-104
4	IRMA, Anand	150	80-90	8-8.5	94-100
5	NIRMA, Ahmedabad	250	120	10-11	83-92
6	Vatsalya International School, Borsad	50	Currently no feeding	-	80
7	Santarm Mandir, Karamsad	85	Cattle dung	-	-

Consultancy Projects

- Received a consultancy project from M/s. CHEM Process Systems Pvt Ltd., Ahmedabad for conducting feasibility studies on bio-methanation potential of cotton stalk i.e. cellulosic and hemi-cellulosic fractions.
- Received a consultancy project from M/s. Petlad Sojitra Taluka Sauraurja Utpadak Sahkari Mandli, Petlad for a pre-feasibility study for bio-gas production and manure value chain management in Rampura village

Technical guidance

- Tender drafting and technical evaluation of the bids for a 470 kWp ground-mounted on-grid PV plant was done for Charotar Arogya Mandal by Er. Asim Joshi

Technology Transfer

Odourless patented bio-methanation technology was transferred to two licensees viz.

M/s. Parbhani Agrotech Pvt Ltd., Aurangabad & M/s. Urja Biosystems Pvt Ltd, Pune.

Patent

- A Patent was granted for the application jointly filed by Department of Biotechnology and Sardar Patel Renewable Energy Research

Institute on "Enzymatic hydrolysis of biomass" (Patent no. 381142) on November 02, 2021.

Memorandum of Understanding

- MoU signed with M/s. Petlad Sojitra Taluka Sauraurja Utpadak Sahkari Mandli, Petlad on September 27, 2021 for setting-up bio-methanation projects and provide complete technical back-up support for the projects.
- MoU signed with M/s. Urja Biosystems Pvt Ltd, Pune, Maharashtra on October 7, 2021 to market and sell SPRERI designed and patented bio-methanation technology throughout India on non-exclusive basis.
- MoU signed with M/s Parbhani Agrotech Pvt. Ltd., Aurangabad, Maharashtra on October 9, 2021 to market and sell SPRERI designed and patented bio-methanation technology throughout India on non-exclusive basis.
- MoU with SRM Institute of Science and Technology, Chennai on October 22, 2021 (a) to promote and enhance academic and research interaction and collaboration between the SPRERI and SRMIST in areas of multi interest for mutual benefit; (b) on developing renewable energy based energy park at SRMIST with support from SPRERI and (c) to provide a formal platform for initiating and facilitating related pursuits.
- MoU signed with M/s. EcoSattva Environmental Solutions, Aurangabad to conduct awareness for solid waste management in 300 commercial establishments in Vallabh Vidyanagar, Karamsad and Anand Nagarpalika on December 21, 2021.

Recognitions & Academic Activities

- Project Title “*Catalytic/ non-catalytic oxidative fast pyrolysis of agro-residues and system evaluation*” for B.Tech students (Ms. Krishna Chudasama & Mr. Dhwanit Tamboli) guided by Dr. Geeta Kumari has been awarded third rank at Project Expo 2021 organized by the Industry Institute Interaction Cell, BVM Engineering College in association with BVM Alumni Association on June 9, 2021.
- Received renewal recognition of Scientific and Industrial Research Organization (SIRO) from Department of Scientific and Industrial Research (DSIR). Validity upto 2025.
- Dr. Shaishav Sharma appointed as Subject Lead Expert for UK-India Bioenergy Project for Algal Biofuels category in March 2022.
- Dr. Shyamali Sarma made an oral presentation on the research work entitled “Micro-algal bio-diesel production and protein extraction from isolated *Chlorella sorokiniana-74*” at ACES conference held on March 25, 2022 organized by IISER, Bhopal and was awarded a Best Presenter in the technical session on bio-energy.
- Dr. Madhuri Narra was appointed a Member of Internal Steering Committee of Gujarat State Biotechnology Mission (GSBTM), Gandhinagar for providing services for technical evaluation of project proposals for the current financial year.

Graduate & Post-graduate Dissertations

Student	Institute	Programme	Duration	Division	Research Topic
Mr. Vikram Mahto	BVM Engineering College, Sardar Patel University	Bachelor of Mechanical Engineering	December 22, 2021 to April 21, 2022	Thermo-Chemical Conversion Division	Theoretical analysis and experimental evaluation of biomass pyrolysis system
Mr. Kirti Mangaliya	BVM Engineering College, Sardar Patel University	Bachelor of Mechanical Engineering	December 22, 2021 to April 21, 2022	Thermo-Chemical Conversion Division	Theoretical analysis and experimental evaluation of biomass pyrolysis system
Mr. Abhishek Patel	G.H. Patel College of Engineering & Technology, V.V. Nagar	Bachelor of Chemical Engineering	January 03 to March 27, 2022	Thermo-Chemical Conversion Division	Production of activated carbon from groundnut shell bio-char : A pilot-scale study
Mr. Hinal Vachhani	G.H. Patel College of Engineering & Technology, V.V. Nagar	Bachelor of Chemical Engineering	January 03 to March 27, 2022	Thermo-Chemical Conversion Division	Transformation of the cotton stalk and groundnut shell into bio-fuels and activated carbon using thermo-chemical processes

Student	Institute	Programme	Duration	Division	Research Topic
Ms. Komal Nathvani	Silver Oak Institute of Science, Silver Oak University, Ahmedabad	Masters in Microbiology	February 07 to May 26, 2022	Bio-chemical Conversion Technology Division	Isolation and identification of Poly Hydroxy Alkanoate (PHA) producing bacterial strains for production and extraction of PHA

Publications

1. Meisam Sadi, Ahmad Arabkoohsar, Asim Kumar Joshi (2021). Techno-economic optimization and improvement of combined solar-powered cooling system for storage of agricultural products. *Sustainable Energy Technologies and Assessments*, 45; 101057.
2. Shyamali Sarma, Shaishav Sharma, Darshan Rudakiya, Aesha Patel, Vinod Rathod, Jinal Upadhyay, Madhuri Narra (2021). Valorization of micro-algae biomass into bioproducts promoting circular bioeconomy: a holistic approach of bio-remediation and bio-refinery. *3 Biotech*, 11, 378.
3. AJ Shah, B. Soni & SK Karmee. Locally available agro-residues as potential sorbents: modelling, column studies and scale-up. *Bioresour. Bioprocess.* 8, 34 (2021). <https://doi.org/10.1186/s40643-021-00387-1>
4. AJ Shah, B. Soni & SK Karmee. Application of cotton stalk biochar as a bio-sorbent for the removal of malachite green and its microwave-assisted regeneration. *Energ. Ecol. Environ.* (2021). <https://doi.org/10.1007/s2-00217-021-40974>
5. Milan Sojitra, Sachin Gupta, Falgun Raval, Arunendra Tiwari, Asim Joshi (2022). Recent advancements and challenges in solar thermal energy storage using nano-enhanced phase change materials, Chapter 1, *Nanofluid Applications in Green Energy Technologies*, Nova Science Publishers.
6. Asim Joshi, Sachin Gupta, Arunendra Tiwari, Falgun Raval, Milan Sojitra, (2022). Experimental study of vacuum tube heat pipe-based solar collector for cooking application. *Smart Technologies for Energy, Environment and Sustainable Development Vol. 2*, pp 517–524.
7. Shaishav Sharma, Priyank Kachhia, Vaishali Shukla, Aesha Patel, Vinod Rathod, Madhuri Narra (2022). Valorization of lignin into nano-particles and nano-gel: characterization and application. *Bioresource Technology Reports*, 18, 101041.
8. M Parmar, B Soni, AJ Shah, SK Karmee. Pyrolysis of pellets prepared from groundnut shell and crude glycerol: in-situ utilization of pyro-gas and characterization of products. *Journal of Material Cycles and Waste Management* (Under review).

Conferences, Workshops & Meetings

National Conferences

Invited Lectures/Judge

S. No.	Details of the programme	Date	Scientist/ Research staff
1	Virtual lecture on “Latest trend in solar energy research and application” at Mechanical Department, Amity University, Raipur	April 09, 2021	Dr. Arunendra Tiwari
2	Acted as Judge of Competition on clean energy revolution an Institute of Electrical and Electronics Engineers (IEEE) the Power and Energy Society (PES) day 2021 event organized by IEEE GCET Industry Application Society (IAS)-PES Chapter	April 22, 2021	Dr. Arunendra Tiwari
3	Virtual lecture on “Latest trend in solar energy research and application” at Mechanical Department, G.H. Rasoni College of Engineers, Jalgaon, Maharashtra	June 01, 2021	Dr. Arunendra Tiwari
4	Virtual lecture on “Solar Technologies for Agriculture and Domestic Sector” for the online training programme on “Climate Smart Agriculture and Efficient Water Management” Organized by EEI, Anand	August 13, 2021	Er. Asim Kumar Joshi

International Conference

S. No.	Details of the programme	Date	Scientist/ research staff
1	2 nd National and 1 st International Conference on Advances in Fluid Flow and Thermal Sciences (ICAFFTS-2021) organized by Sardar Vallabhbhai National Institute of Technology, Surat. <ul style="list-style-type: none"> “Material Recovery from end-of-life Solar Photovoltaic Module through Thermal and Chemical Processes” 	September 24-25, 2021	Dr. Sachin Gupta (Co-author)

Meeting / Workshops

S. No.	Details of the programme	Date	Scientist/Research staff
1	Attended the Introductory meeting with Ganpat University for possible collaborative work	May 08, 2021	<i>SPRERI:</i> Dr. Gaurav Mishra Dr. Madhuri Narra Er. Asim Johi Dr. Geeta Kumari Er. Samir Vahora <i>Ganpat University, Ahmedabad:</i> Director of Research, Dr. Ajay Gupta and other faculty members involved in RE
2	Attended the introductory meeting with Abelon clean energy Ahmedabad for possible collaborative work and presented work on BCT & TCCT technologies	May 18, 2021	<i>SPRERI:</i> Dr. Gaurav Mishra Dr. Madhuri Narra Dr. Geeta Kumari <i>Abelon officials:</i> Er. Ashwin Tirpude
3	Attended “Fundamentals and Applications of CFD” by Department of Mechanical Engineering, SVNIT, Gujarat, India	May 25, 2021	Er. Bhavin Soni
4	Virtual meeting with Civil Society Organizations and other development partners on 1st June 2021 to prevent the surge of Covid cases and other related issues organized by Niti Aayog	June 01, 2021	Er. Asim Kumar Joshi
5	5 th Danish side Steering Committee Meeting for “Indo-Danish bilateral project” at Aalborg University, Denmark	June 15, 2021	Dr. Gaurav Mishra Er. Asim Kumar Joshi
6	3 rd Indian side Steering Committee Meeting for “Indo-Danish bilateral project” at SPRERI	June 25, 2021	Dr. Gaurav Mishra Er. Asim Kumar Joshi Dr. Sachin Gupta
7	Discussion on SPRERITECH solar thermal technologies and Algae research work with Dr. Rele (CEO, ICE Strategic Business Advisors)	August 06, 2021	Dr. Gaurav Mishra Dr. Madhuri Narra Er. Asim Kumar Joshi

S. No.	Details of the programme	Date	Scientist/Research staff
8	Signing MoU with M/s. Urja Biosystems Pvt Ltd, Pune regarding technology transfer of Odourless Patented Bio-methanation Technology	September 07, 2021	<i>SPRERI:</i> Dr. Gaurav Mishra Dr. Madhuri Narra Er. Samir Vahora <i>M/s. Urja Biosystems, Pune:</i> Mr. Satish Bharad Mr. Suhas Hingane
9	Meeting with Chairman Petlad Sojitra Taluka Saururja Utpadak Sakhari Manali Limited (PSTSUSM), Petlad regarding Pre-feasibility report (PFR) & Detailed project report (DPR) on manure value chain management and mixed organic waste based bio-methanation plant	September 27, 2021	<i>SPRERI:</i> Dr. Gaurav Mishra Dr. Madhuri Narra Er. Samir Vahora <i>PSTSUSM, Petlad:</i> Mr. Tejasbhai Patel Mr. Hardik Patel
10	22 nd meeting of renewable energy sources sectional committee, MED 04 in joint session with 15 th meeting of solar thermal energy	October 08, 2021	Er. Asim Kumar Joshi
11	Virtual meeting with M/s. Urja Biosystems Pvt Ltd, Pune regarding 3.5 TPD bio-methanation plant	October 16, 2021	<i>SPRERI:</i> Dr. Gaurav Mishra Dr. Madhuri Narra Er. Samir Vahora <i>M/s. Urja Biosystems, Pune:</i> Mr. Gajanan Patil Mr. Satish Bharad
12	Meeting with M/s. Urja Biosystems Pvt Ltd, Pune regarding plan of action of 3.5 TPD bio-methanation plant	October 20, 2021	<i>SPRERI:</i> Dr. Gaurav Mishra Dr. Madhuri Narra Er. Samir Vahora Er. Siddharth Goswami <i>M/s. Urja Biosystems, Pune:</i> Er. Arhaan Chaudhari Mr. Vicky
13	Consultation workshop on “Research & innovation priorities for solar thermal in India” organized by the delegation of EU to India with support from MNRE	October 28, 2021	Dr. Sachin Gupta

S. No.	Details of the programme	Date	Scientist/Research staff
14	A virtual meeting was held for discussion on possible collaboration for R&D work on nanofluid with Prof. Wagh (Principal) & Dr. Hemant, Head (Mech. Dep.) SRICT, Ankleshwar	October 29, 2021	Dr. Gaurav Mishra Er. Asim Kumar Joshi Dr. Sachin Gupta
15	Attended a 10 Nos. one day Techneev@75 programmes organized by SEED Division, Department of Science and Technology, New Delhi	November 2021 – March 2022	Dr. Gaurav Mishra Er. Samir Vahora
16	Participated in India International Science Festival IISF 2021, National Social Organizations and Institutions Meet (NSOIM), Panji, Goa	December 11-13, 2021	Dr. Shaishav Sharma Er. Samir Vahora
17	7th Annual review workshop of CRP on EA, PF and MIS	December 15-17, 2021	Dr. Geeta Kumari Er. Bhavin Soni Er. Urvish Patel Er. Shardul Amin
18	6 th Steering Committee Meeting for “Indo-Danish bilateral project” at Aalborg University, Denmark	December 21, 2021	Dr. Gaurav Mishra Er. Asim Kumar Joshi
19	XXV Workshop of All India Coordinated Research Project on “Energy in agriculture and agro-based industries” organized by CIAE, Bhopal	January 11-13, 2022	All scientific and technical staff of BCT, SED, TCCT & Extension division
20	PAC meeting project progress presentation for Indo-Danish bilateral DST project	January 13, 2022	Dr. Gaurav Mishra Er. Asim Kumar Joshi Dr. Sachin Gupta
21	Meeting with M/s. Chem Process systems Pvt. Ltd., Ahmedabad for consultancy projects and prospects of future collaborations	January 17 & March 11, 2022	<i>SPRERI:</i> Dr. Gaurav Mishra Dr. Madhuri Narra Er. Samir Vahora Dr. Shaishav Sharma <i>M/s. Chem Process Systems Pvt. Ltd., Ahmedabad:</i> Mr. Jayesh Parikh, MD, Sarosh Ginwalla, Director Mr. Dhiraj Nimje

S. No.	Details of the programme	Date	Scientist/Research staff
22	Smart Meter Industry- Achieving 100 Million Smart Meters by 2023 to shape India's Power	January 27, 2022	Dr. Geeta Kumari Er. Bhavin Soni Er. Urvish Patel Er. Shardul Amin
23	Attended a 2 nd EC meeting under SUNIL programme, SEED Division, DST, New Delhi and presented final progress report of DST Core – 2 nd Phase programme	February 07-08, 2022	Dr. Gaurav Mishra Er. Samir Vahora
24	Virtual meeting with Deans and HoDs of SRM Institute of Science and Technology (SRMIST) and SPRERI team on faculty induction, development programs, student internship program, UG students industrial visit, student projects, collaborative research project proposals, co-organized conferences, workshops, and webinars	February 09, 2022	<i>SPRERI:</i> Dr. Gaurav Mishra Dr. Madhuri Narra Er. Asim Joshi <i>SRMIST, Chennai:</i> Dr. Kamtha D Arunachalam Dr. K. Anbalagan Dr. A. Saravanakumar Dr. R. Suriyaprakash Dr. B. Samuel Jacob Dr. A. Shobana Devi Dr. T. Veeramakali Dr. P. Supraja Dr. Sachikanta Nanda Dr. T Kalaivani Dr. K. T. Vijay Karthikeyan Dr. R. Senthil Dr. Soumyaranjan Routray Dr. Kamlesh Golhani Dr. S. Umamageshwari Dr. S. Muthulakshmi Dr. G Keerthiga Dr. Sowwmya
25	Participated in one day Techneev@75 programme on “Energy Access for Prosperous Society” organized by SEED Division, Department of Science and Technology, New Delhi	February 11, 2022	Dr. Gaurav Mishra Er. Samir Vahora Mr. Paresh Mer

S. No.	Details of the programme	Date	Scientist/Research staff
26	4 th steering committee meeting for “Indo-Danish bilateral project” at SPRERI	February 24, 2022	Dr. Gaurav Mishra Er. Asim Kumar Joshi Dr. Sachin Gupta
27	Attended the Internal Steering Committee of Gujarat State Biotechnology Mission (GSBTM), Gandhinagar for scrutinizing new proposals for the current financial year	March 11 & 17, 2022	Dr. Madhuri Narra
28	3 rd Hybrid Conference & Digital Exhibition on “AatmaNirbhar Bharat – Making India a Global Manufacturing Hub for Renewable Energy.	March 22, 2022	Dr. Geeta Kumari
29	Attended a meeting of EMA components under All India Coordinated Research Project on Energy in Agriculture and Agro-based Industries organized by CIAE, Bhopal	March 23, 2022	Er. Samir Vahora
30	Techno-commercial negotiations meeting for 470 kWp ground-mounted PV plant held at Management Center, Bhaikaka University	March 25, 2022	Er. Asim Kumar Joshi

Webinars/seminars:

S. No.	Details of the programme	Date	Scientist/Research Staff
1	Attended a webinar on “Bio-STP” conducted by National Productivity Council, an autonomous organization under the Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Commerce & Industry, Govt. of India	May 22, 2021	Dr. Madhuri Narra
2	Attended an online talk on “Feature funding opportunities” organized by Navjivan Centre for Development	September 15, 2021	Dr. Madhuri Narra
3	Attended a lecture series on “Paradigm shift in 4 th & 5 th generation agriculture” organized by College of Agricultural Engineering & Technology, Anand Agricultural University, Godhra	September 15, 2021	Dr. Madhuri Narra Dr. Shaishav Sharma
4	Attended Bio-summit 2021, “Farm to fuel: sustainable bioenergy solution for Aatmanirbhar Bharat” organized by CII	September 23, 2021	Dr. Madhuri Narra Dr. Shaishav Sharma

S. No.	Details of the programme	Date	Scientist/ Research Staff
5	Attended an online webinar on the topic “Elemental analysis by CHNS/O analyzer” organized by SICART	October 08, 2021	Dr. Shyamali Sarma Dr. Shaishav Sharma Mrs. Aesha Patel Ms. Nidhi Patel Mr. Alok Sivaprasad
6	Attended IISF-2021 and exhibited SPRERI’s technologies and research by putting-up a stall at the National Social Organisations and Institutions Meet (NSOIM) organized at Panji, Goa	December 10-14, 2021	Er. Samir Vahora Dr. Shaishav Sharma
7	Participated in the International seminar on “Renewable energy resources: new technologies of 2022” organized by Chemical Engineering Department, Nirma University, India and funded by Shastri Indo-Canadian Institute	March 05, 2022	Mrs. Aesha Patel
8	Attended the virtual knowledge session on “Green hydrogen-based chemicals” organized by Indo German Chamber of Commerce	March 22, 2022	Mrs. Aesha Patel

Presentations:

S. No.	Details of the programme	Date	Scientist/ Research Staff
1	Presentation to Ganpat university about SPRERI technologies during interaction meeting	May 8, 2021	Dr. Gaurav Mishra Dr. Madhuri Narra
2	Presented the progress of the project entitled “Introduction of SPRERI-TECH fluidized bed gasification system in Poha making industries for improved efficiency and working environment” funded by SSTP, DST	May 13, 2021	Dr. Gaurav Mishra
3	Presentation on the submitted project proposal in response to the scheme “ <i>Biotechnology Based Programmes for Societal Development</i> on “Empowerment of Women SHG from small dairy farming community through bio-technological interventions in manure value chain management” to the review committee members of DBT	May 14, 2021	Dr. Gaurav Mishra Dr. Madhuri Narra

S. No.	Details of the programme	Date	Scientist/ Research Staff
4	Presentation to Abelon Clean Energy, Ahmedabad for possible collaborative work on BCT & TCCT technologies	May 18, 2021	Dr. Gaurav Mishra
5	Presented the annual progress of the project entitled “Implementation of a self-sustainable model for energy generation by adopting a patented clean technology for conversion of 3.5 TPD of mixed organic waste into methane and bio-fertilizer” during review committee meeting of DBT	July 1, 2021	Dr. Madhuri Narra
6	Presentation on the submitted R&D proposal on “Microbial polymer production inexpensive carbon sources: Process optimization and economic feasibility study” to the members of supplementary meeting of fifth Scientific & Technical Appraisal & Advisory Group of Energy, Environment & Bioresource based Applications	July 28, 2021	Dr. Shyamali Sarma
7	Presentation on “SPRERI’s integrated micro-algae based dairy effluent treatment process” to Mr. Rele, CEO, ICE Strategic Business Advisors	August 11, 2021	Dr. Shaishav Sharma
8	Delivered an invited lecture on the occasion of Ozone day organized by CAE Media Group at Madarsa High School, Anand	September 16, 2021	Dr. Shaishav Sharma
9	Presented progress of the new proposal submitted for the year 2021-22 during review meeting of ICAR_AICRP_EAAI scheme	October 26-27, 2021	Dr. Madhuri Narra
10	Presented progress of the DBT ongoing projects to Technical Expert Committee of Energy Biosciences	December 15, 2021	Dr. Madhuri Narra
11	Presented progress of the ongoing & new projects during VII annual review meeting of ICAR_CRP on EA scheme	December 15-17, 2021	Dr. Madhuri Narra
12	Presented progress of the ongoing & new projects during review meeting of ICAR_AICRP_EAAI scheme	January 11-13, 2022	Dr. Madhuri Narra

S. No.	Details of the programme	Date	Scientist/ Research Staff
13	Presented progress of the DBT ongoing 3.5 TPD implementation project to the Project Monitoring and Mentoring Committee	February 15, 2022	Dr. Madhuri Narra
14	Delivered an invited lecture on “Enzyme production using lignocellulosic biomass” during Winter school on crop residues utilization and management for clean energy and environment organized by ICAR-CIAE, Bhopal	February 23 & March 15, 2022	Dr. Madhuri Narra
15	Presentations on submitted R&D proposals for financial support to the Technical Advisory Committee at GSBTM, Gandhinagar	March 24, 2022	Dr. Shyamali Sarma Dr. Shaishav Sharma
16	Oral presentation on the research work carried out (Synthesis of lignin nanoparticles for antioxidant and anticorrosion application) at ACES conference organized by IISER, Bhopal	March 26, 2022	Dr. Priyank Kachhia

Visitors to the Organization

- Mr. Satish Bharad, Business Development Manager & Mr. Suhas Hingane, Business Associate from M/s. Urja Biosystems Pvt Ltd., Pune visited SPRERI on September 7, 2021.
- Mr. Jayesh Parikh, MD, Sarosh Ginwalla, Director, Projects, Mr. Dhiraj Nimje from M/s. Chem Process Systems Pvt. Ltd. visited SPRERI on January 17 & March 11, 2022.
- Mr. Anindya Lehri, Consultant (Ex-Director), A.T.E. Enterprises Pvt. Ltd, Pune visited SPRERI on February 9, 2022.

Industry visits and surveys

- Dr. Sachin Gupta visited M/s Soft-Tech Renewable Energies (STRE), Ludhiana, and their field installation on February 8-9, 2022 to get acquainted with STRE’s solar concentrating technology to adapt in the DST project.
- Er. Asim Joshi & Dr. Sachin Gupta visited HMX (A business unit of A.T.E. group), Ahmedabad on February 15, 2022, to discuss and get acquainted with HMX’s concentrating solar thermal system for exploring the possibility to adapt in DST project.
- Er. Asim Joshi and Mr. Paresch Mer visited Nandurbar District, Maharashtra during 6-9 March 2022 for the survey of villages to explore possible renewable energy-based interventions.

Director

- Dr. Gaurav Mishra

Solar Energy Division

- Er. Asim Kumar Joshi, In-charge
- Dr. Arunendra Kumar Tiwari (upto 04.09.2021)
- Er. Milan Sojitra
- Mr. Mahendra Padhiyar
- Dr. Sachin Gupta
- Dr. Siddharth Ramachandran (since 09.02.2022)
- Er. Falgun Raval (upto 22.02.2022)
- Mr. Mukesh Jadav

Bio-conversion Technology Division

- Dr. Madhuri Narra
- Dr. Shaishav Sharma
- Er. Kartikkumar Takkar
- Dr. Samir Dedania (upto 13.04.2021)
- Mrs. Aesha Patel
- Mr. Alok Sivaprasad Vishwakarma
- Er. Siddharth Goswami (upto 20.01.2022)
- Mr. Harmar Parmar
- Mr. Ashok Mochi
- Dr. Shyamali Sarma
- Dr. Vaishali Shukla (upto 21.06.2021)
- Dr. Priyank Kachhia (upto 29.03.2022)
- Mrs. Jinal Upadhyay (upto 25.05.2021)
- Ms. Nidhi Patel
- Er. Raiyan Vahora (upto 19.06.2021)
- Mr. Ashok Harijan
- Mrs. Manjula Vadhel

Thermo-Chemical Conversion Technology Division

- Dr. Geeta Kumari
- Er. Urvish Patel
- Mr. Ashok Patel
- Er. Shardul Amin
- Er. Bhavin Soni

Technology Transfer & Extension Division

- Er. Samir Vahora
- Er. Shradhdha Pandya (upto 12.01.2022)
- Mr. Shailesh Solanki
- Mr. Paresh Mer
- Mr. Minesh Suthar

Administration

- Mr. Keyur Prajapati
- Mr. Hiteshkumar Dalwadi (upto 30.11.2021)
- Mr. Hasmukh Vaghela
- Mr. Dahya Harijan
- Mr. Rahesh Machhi
- Mr. Ishwar Harijan
- Ms. Pragna Dave
- Mr. Harshad Suthar
- Mr. Bhupendra Prajapati
- Mr. Ramesh Bhoi
- Mr. Bhupat Parmar

Balance Sheet

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE - VALLABH VIDYANAGAR BALANCE SHEET AS ON - 31 - 03 - 2022

FUNDS & LIABILITIES	2021	2022	ASSETS	2021	2022
CAPITAL FUND			FIXED ASSETS		
As per last year	₹ 10,82,669.20	₹ 10,82,669.20	1. Furniture & Fixtures	₹ 2,49,808.62	₹ 2,49,808.62
PROJECT FUND			2. Electric Fittings	₹ 1,62,350.85	₹ 1,62,350.85
Balance from last year	₹ 1,92,75,366.58	₹ 2,92,49,245.67	Add : During the year	₹ 0.00	₹ 0.00
Add / Less during the year (Annexure - A)	₹ 99,73,879.09	₹ 1,20,82,320.00	3. Mobile Phone	₹ 1,62,350.85	₹ 1,62,350.85
	₹ 2,92,49,245.67	₹ 1,71,66,925.67	4. Institute Equip.(R & D / Others)	₹ 19,600.00	₹ 19,600.00
			5. Car - GJ-23 AF-0282	₹ 10,71,372.00	₹ 10,71,372.00
			6. New Jeep - GJ-23-GA-0488	₹ 5,85,597.00	₹ 5,85,597.00
				₹ 8,34,000.00	₹ 8,34,000.00
EAR MARKED FUND				₹ 29,22,728.47	₹ 29,22,728.47
1. Building Fund Provision			INVESTMENT		
Add : During the year	₹ 33,64,376.00	₹ 33,64,376.00	1. Fixed Deposit	₹ 3,55,04,862.68	₹ 2,97,44,960.68
			2. Deposit in LIC - Graduity Scheme	₹ 76,95,445.80	₹ 86,45,687.20
				₹ 4,32,00,308.48	₹ 3,83,90,647.88
2. Depreciation Investment Fund	₹ 4,55,244.00	₹ 4,55,244.00	LOANS & ADVANCES		
3. R & D Fund (As per last year)	₹ 81,03,647.83	₹ 81,03,647.83	1. Tax Deduction at Source	₹ 8,89,673.06	₹ 7,44,340.06
Add : During the year	₹ 0.00	₹ 13,66,170.00	2. Telephone Deposit	₹ 20,313.00	₹ 20,313.00
Less : During the year	₹ 81,03,647.83	₹ 94,69,817.83	3. CGM Deposit (Oil Diesel & Petrol)	₹ 12,400.00	₹ 12,400.00
			4. Indian Oxygen Ltd., Deposit	₹ 4,252.94	₹ 4,252.94
DONATION			5. Mobile Phone Deposit	₹ 4,680.00	₹ 4,680.00
Balance from last year	₹ 12,34,001.00	₹ 18,20,101.00	6. Broad Band Security Deposit	₹ 3,000.00	₹ 3,000.00
Add : During the year	₹ 5,86,100.00	₹ 1,16,000.00	7. Gas Cylinder Deposit	₹ 10,350.00	₹ 10,350.00
	₹ 18,20,101.00	₹ 19,36,101.00	8. Security Deposit (GEB - New DP)	₹ 1,00,920.00	₹ 1,00,920.00
			9. Loan to Staff & Advance to Project	₹ 7,29,642.00	₹ 7,29,642.00
PROJECT EQUIPMENT			10. Intrest Accrued	₹ 5,22,661.01	₹ 5,44,069.01
Depreciated value of Equip.from last year	₹ 10,79,70,513.60	₹ 11,39,32,228.51	11. Gujcost to be recover	₹ 0.00	₹ 0.00
Add : During the year	₹ 59,61,714.91	₹ 1,28,15,823.00	BALANCE :		
Less : Depreciation Annexure - C	₹ 11,39,32,228.51	₹ 12,67,48,051.51	Bank Balance	₹ 1,27,05,975.24	₹ 82,66,713.89
			Cash Balance	₹ 87,168.00	₹ 2,34,608.00
DEPRECIATION FUND				₹ 1,27,93,143.24	₹ 85,01,321.89
As per Block - Annexure - B	₹ 62,92,646.30	₹ 64,35,253.30			
LIABILITIES					
1. Contigent Development Fund	₹ 1,33,400.00	₹ 1,33,400.00			
2. Graduity Fund	₹ 76,95,445.80	₹ 86,45,687.20			
3. Endowment Fund -	₹ 13,59,239.75	₹ 14,00,016.75			
Add : During the year	₹ 40,777.00	₹ 42,001.00			
Less :	₹ 0.00	₹ 0.00			
Annexure - D	₹ 14,00,016.75	₹ 14,42,017.75			
4. Staff Welfare Fund	₹ 6,95,984.50	₹ 9,51,774.95			
5. Share & Care Fund	₹ 1,52,835.00	₹ 1,52,835.00			
6. Quiz Programme Fund	₹ 58,262.00	₹ 58,262.00			
7. Maintenance Fund (Core Grant)	₹ 7,25,879.00	₹ 7,25,879.00			
Extension activity fund	₹ 0.00	₹ 0.00			
Income & Expenditure A/C					
SURPLUS / LOSS					
From Last/current Yr Balance Sheet	-₹ 1,44,609.05	-₹ 15,680.85			
Add - During the year	₹ 1,28,928.20				
TOTAL					
Less - During the year		₹ 15,896.80			
TOTAL	₹ 15,680.85	-₹ 31,577.65			
TOTAL	₹ 6,12,14,072.20	₹ 5,19,88,665.25	TOTAL	₹ 6,12,14,072.20	₹ 5,19,88,665.25


Accounts Officer
Sardar Patel Renewable
Energy Research Institute
Accounts Officer




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


Director
Sardar Patel Renewable
Energy Research Institute
Director

Date :- 25.07.2022
Place :- Vallabh Vidyanagar



Acronyms

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

List of Technologies for Commercialization

- Thermal battery-based solar refrigerator
- Standalone type PV integrated solar low tunnel dryer
- Forced circulation solar cabinet dryer
- Solar-based wax melting system
- Single-axis sun tracker for photovoltaic panels
- Solar-biogas hybrid cold storage system
- Portable double-glazed solar dryer
- Solar evacuated tube with heat pipe-based desalination system
- Solar evacuated tube with heat pipe collector-based pressure-cooking system
- Thermal energy storage integrated Solar concentrating cooking system
- Solar photovoltaic-thermal (PVT) hybrid collector for air heating
- Thermal energy storage based Indirect solar dryer
- Nanofluid for performance enhancement of solar thermal collectors
- Conversion of fruit and vegetable residue to bio-gas and manure
- Conversion of kitchen residue to bio-gas and manure
- Biogas generation from agro-industrial effluent
- Bio-methanation of dairy effluent scum
- Up-draft biomass gasifiers for thermal applications
- Open core down draft biomass gasifier systems for thermal and power applications
- Biomass combustor-cum-hot air generator
- Improved biomass cookstoves (batch and continuous operation)
- Movable platform type wood cutter for preparing feedstock for gasifier
- Glass roof tiles for natural sunlight in the tribal rural house

Acknowledgments

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

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



SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE
POST BOX NO:2, NR. BVM ENGINEERING COLLEGE
VALLABH VIDYANAGAR, GUJARAT, INDIA-388 120