SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE

SPRERI

Striving for Excellence

Annual Report | 2020-21

Sardar Patel Renewable Energy Research Institute

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Highlights of the Year

In the last few decades, the world has seen changes in global temperature and this year also an increase in temperature is witnessed. The IPCC has clearly warned that in addition to understanding issues related to climate change, no time can be lost in addressing and acting with scale and pace and have highlighted the need to offset carbon to the extent possible. One way of offsetting carbon is by introducing renewable energy (RE) to replace fossil fuels to meet the energy needs of different applications

In line with the focus on RE, India did set targets of installing 175 GW of RE by the end of 2022. With the impetus provided by the Government, the country was not only able to meet the target of installation of 100 GW of RE power (excluding hydro) ahead of its target date but new targets were set by the Govt to install over 280 GW (~ 60%) from solar PV in the total of 450 GW of RE by the end of 2030.

In line with the thrust areas decided by the Govt of India, SPRERI is working extensively in developing technologies and/or processes in the RE sector and solid waste management through their patented and proven technologies.

In the area of solid waste management, SPRERI is constructing a 3.5 TPD bio-methanation plant in Karamsad in Gujarat. The project was sanctioned by the Department of Biotechnology (DBT), Govt of India under their clean energy scheme.

At SPRERI, the bio-chemical conversion division is addressing the burning issue of stubble burning which is seen in Punjab and Haryana every winter, with its team working on in-situ and ex-situ management of paddy straw processes. A joint patent has been granted to SPRERI and DBT by the Indian Patent Office, Mumbai for converting rice straw to fermentable sugars at high solid loadings using in-house cellulases. The group is also working on developing lignin-based nano-fibers and nano-gels for different applications.

The thermo-chemical division after up-scaling its loose biomass-based fluidized bed gasification system to 100 kg h^{-1} capacity, is in the process of installing one at a poha making facility in Gujarat. The dhaba-size forced-draft biomass cookstove developed by the team is under rigorous testing in different small and micro industries and dhabas to meet the thermal needs of small dhabas and snack centres etc.

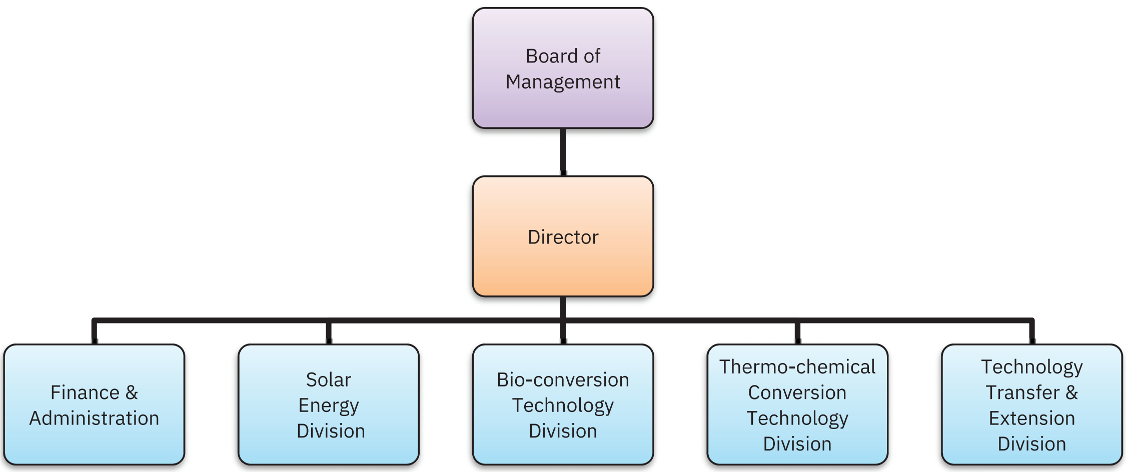
The solar energy division is working mainly on developing technologies for cooking, drying and refrigeration. Under the Indo-Danish bilateral programme in the Department of Science and Technology, the team is working with Aalborg University, Denmark to develop an automated solar-biomass based cold storage system for horticultural produce. The system that has been designed will soon be installed at a farmers farm.

With the constraints of the pandemic, SPRERI has been engaged in various online training programmes during the year. The extension division has installed more than 380 nos. of SPRERI developed improved biomass cookstoves in different parts of Gujarat.

This year due to the covid restrictions SPRERI organised its annual event “Open House” in February in an online mode. The event was inaugurated by Prof. Datta Madamwar, Scientific Advisor, PD Patel Institute of Applied Sciences, Charotar University of Science and Technology, Changa, Gujarat. More than 3000 persons, primarily under graduate and postgraduate students, faculty of engineering, management and science colleges from all over Gujarat participated.

The Organization & Structure

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



Vision & Mission

VISION

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

MISSION

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

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 & Control Systems Division M/s Jyoti Limited, Vadodara
Dr. Nisarg Joshi	Deputy Secretary (RE & Petro branch), Dept. of Energy & Petrochemicals, Govt. of Gujarat, Gandhinagar
Dr. S.G. Patel	Hon. Secretary, Charutar Vidya Mandal Vallabh Vidyanagar
Dr. Datta Madamwar	Scientific Advisor, PD 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

Solar evacuated tube with heat pipe collector for cooking application

A 5 L capacity jacketed pressure cooker was designed, fabricated and retrofitted with the solar ETC heat pipe system, shown in Fig. 1. Tests with and without water were carried out to evaluate the performance of the system developed with new design compared to the older system with jacketed SS pot with cover. It was found that the new system has a much-improved efficiency. The temperature profile observed during the test is shown in Fig. 2. The overall system efficiency is found to be 19% for water boiling. Further, the system was tested to boil potatoes & was able to boil 10 kg-d^{-1} efficiently in 8 h. The tentative cost of the developed prototype is Rs. 60,752/- and simple payback was estimated at ~4 years.

Fig. 1 Solar ETC heat pipe integrated cooking system

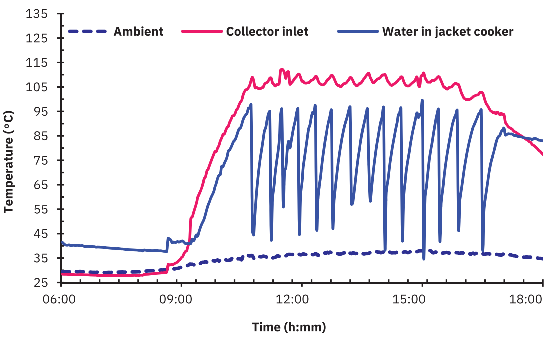


Fig. 2 Temperature profile during the water boiling test

Thermal storage integrated solar concentrating cooker

A parabolic dish type solar concentrator with 4.9 m^2 aperture area was designed and developed in-house with manual tracking as shown in Fig. 3. Stagnation test was carried out to estimate the maximum achievable temperature and it was found that it can generate temperature up to 900°C (Fig. 4).

Fig. 3 In-house developed solar concentrator parabolic dish

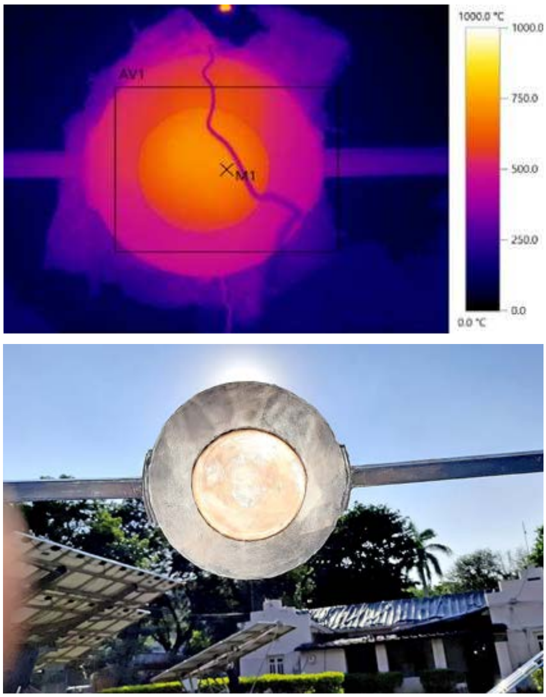


Fig. 4 Thermal image of receiver

Charging and cooking tests were conducted using the fabricated portable thermal storage (PTS) devices as receiver with the developed solar dish. Around 2.7 kg of $NaNO_3$, phase change material (PCM) was used during the tests. As shown in Fig. 5, it took about 1 h and 15 min to completely charge the receiver at about 300°C temperature with an average direct normal irradiance (DNI) 639 Wm^{-2} during morning hours. Comparative cooking tests were carried out for direct cooking on concentrator vs. cooking with the charged PTS device. The observation noted for cooking time of potato, lentil and rice with the PTS device and concentrating cooker is given in Table 1.

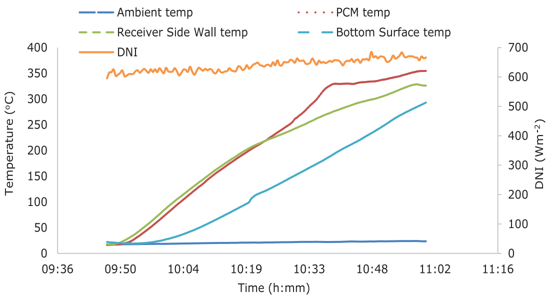


Fig. 5 Charging of concentric vertical fins base receiver

Table 1 Cooking performance with PTS device and concentrator

S. No.	Type of cooking	Product cooked	Dry weight (g)	Cooking time (min)
1	Directly on concentrator	Pigeon pea lentil	200	20
2		Rice	400	15
3	With charged PTS device only	Pigeon pea lentil	150	45
4		Rice	300	40

From the experiments, it has been found that the cooking time with the concentrator is less in comparison with cooking using the PTS device. This is due to low storage temperature of the PTS device as well as low thermal conductivity of the PCM.

The tentative cost of the system is Rs. 40,000/- with simple payback period of 5.6 and 3.0 years replacing domestic LPG and wood, respectively. The proposed system is suitable for a family of 4 persons and can meet the requirements of the following cooking processes-boiling, curry making and steaming. Further development of the system is under progress.

1.2 Solar Drying

Thermal energy storage-based indirect solar dryer

The developed testing prototype consists of four ETC heat pipe collectors, thermal energy storage tank, heat exchanger and drying chamber. During its operation, the air and water flow was manually controlled through in-line gate valves and flow meters. For automation of the system, variable frequency drive (VFD) was introduced and integrated with the pumps and blower for controlling water and air flow rate (Fig. 6). In the heat exchanger line, the pump was connected to a temperature controller-based starter.

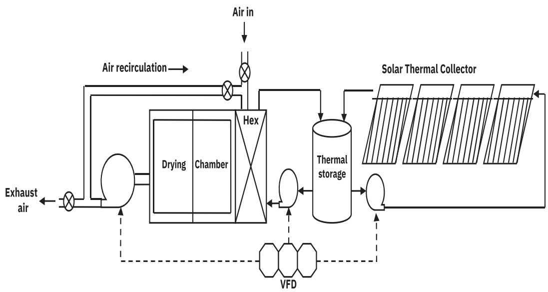


Fig. 6 Schematic of modified system with VFD and air recirculation ducting

The system was tested at air velocity 0.5 ms^{-1} and 1 ms^{-1} in the drying chamber, for determining volume of air that can be heated in single pass through heat exchanger (Hex). The results obtained for the case of single pass of air through heat exchanger are given in Table 2.

Table 2 Hot air generation potential in single pass

Air velocity in drying chamber (ms^{-1})	Average air flow rate ($m^3 h^{-1}$)	Hot air utilization potential (min)
0.5 ± 0.1	840.0	130
1.0 ± 0.1	1779.5	60

For improvement, to have proper air distribution and uniform temperature inside the drying chamber, CFD simulation of the drying chamber was carried out in 2D and necessary modifications were made. Based on the simulation results, modifications i.e., introduction of baffles etc were made and improved air distribution was observed, as shown in Fig. 7 & 8. Further testing of the system with load and re-circulation of hot air is under progress.

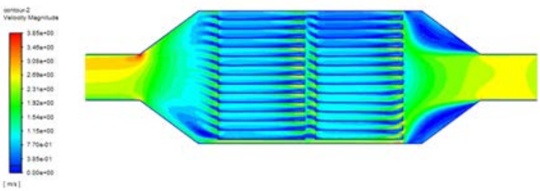


Fig. 7 Air flow distribution in drying chamber

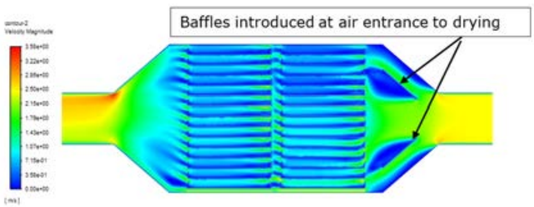


Fig. 8 Air flow distribution after introducing baffles at entry

1.3 Solar Desalination

Solar compound parabolic concentrator (CPC) for desalination of ground water

For improving performance of the system, a simple water-in-tube type CPC collector was procured and its testing was carried out as per IS 16368:2015 for determining its optical efficiency and heat loss co-efficient. The test set-up was arranged as shown in Fig. 9. The specification of the system is as given in Table 3. The concentration ratio of CPC is 2. The system was tested daily for 15 continuous days with different initial temperatures of water in the tank. On testing as per IS 16368:2015, the optical efficiency of the CPC system was observed as 41.25% and day time heat loss coefficient obtained was 0.65. This might be due to the poor insulation on the tank and pipeline. The amount of thermal energy stored by tank water was evaluated around 6.17 kW which is equivalent to evaporate around 9.8 L water. The thermal energy stored was found lower than expected 9 kW, which is enough to evaporate around 14 L water. Further modifications on improvement in system design & performance is in progress.

Fig. 9 Test set-up for performance of CPC collector

Table 3 CPC collector specifications

No. of tubes	20
Tube dimension	1800 x 58 mm
MOC	Aluminium 6063
Thickness of CPC structure	2.8-3 mm
Reflector surface	Silver PET film
Reflectivity	>92%

1.4 Solar Refrigeration

Thermal energy storage for solar-driven cold storage

The objective of this project is to design and develop a compatible thermal energy storage device to integrate it with solar-driven cold storage for maintaining cold room temperature 10 to 20°C during non-sunny hours.

The experimental set-up has been installed which includes cold storage room, vapour-compression machine, PV panel as shown in Fig. 10. The set-up is equipped with all necessary sensors and data logger to record the parameters of interest. The testing of the cold storage with no load is in process without any thermal energy storage. The experiments were conducted for range of cold room temperatures (-10°C to 10°C).

Fig. 10 PV array, cold storage, outdoor and indoor unit

Details of the set-up

1. System capacity: 2.0 TR, Refrigerant: R404A, $T_{min, Evap}$ = -10°C
2. PV array: Polycrystalline, 10 kWp
3. Cold room (gross volume): 29.2 m^3, Insulation: 50 mm

Key findings

1. The Vapour compression refrigeration system (VCRS) with 10 kWp PV array and no thermal energy storage is able to maintain the temperature of cold storage at set temperature of 5°C from 9.30 am to 4.30 pm in the month of February and March.

2. The power drawn by the VCRS and solar radiation follows the same curve. The total energy utilized to maintain the temperature through PV module is 13.24 kWh and the average solar radiation found was 552 Wm^{-2}.

3. Voltage remained constant throughout the day whereas the current followed the radiation curve.

4. There is a frequent turning on & off of the VCRS set-up during the operation. This frequent on-off cycle was attributed to low level of insulation in the cold storage, which resulted in quick thermal gain resulting in rise in temperature inside the cold room. Therefore, it was decided to increase the thickness of insulation of the cold room. A new cold room with increased insulation thickness is under installation.

   For maintaining 5°C, the results of the experiments conducted are shown in Fig. 11.

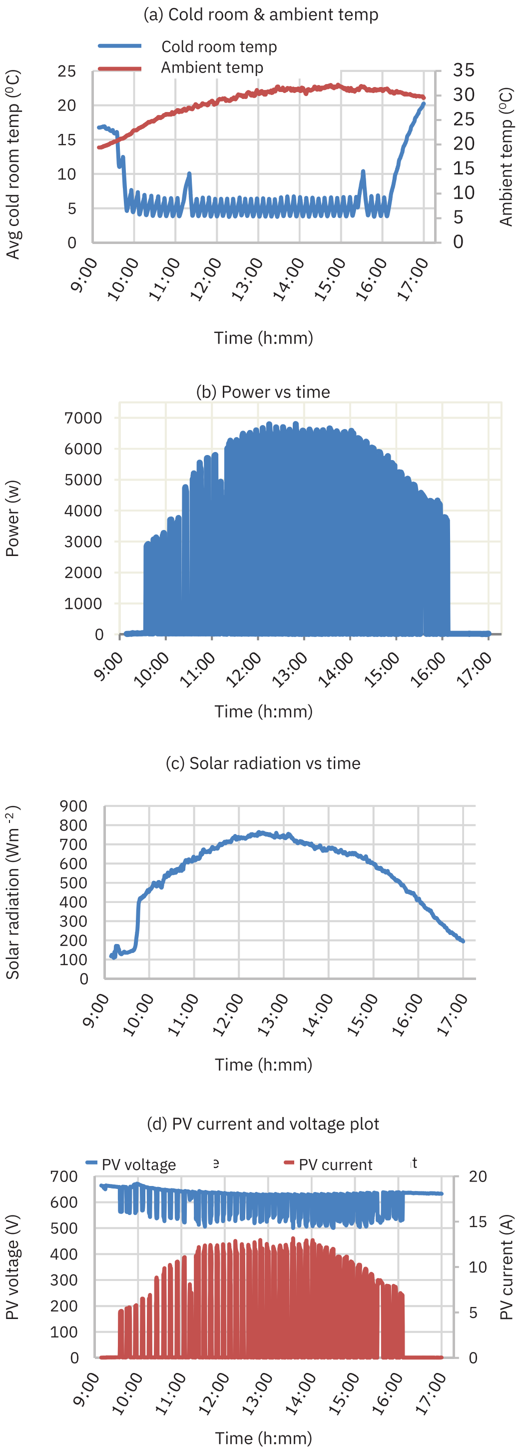


Fig. 11 (a) Average cold room and ambient temperature variation (b) power consumption (c) solar radiation during the experiment (d) PV voltage & PV current variation

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

The progress made under the bilateral Indo-Danish project:

The existing system at College of Food Processing Technology and Bio-energy (FPT-BE), Anand Agricultural University (AAU) was made operational and was tested on approx. a 1000 kg load of unripe banana. The unripe banana was stored for a total of 23 days to explore the potential of the cold room for banana storage. A number of farmers were invited to visit the facility and a mix of opinions with regard to interest were obtained from them.

Using the TRNSYS software, a model for a domestic solar hot water system (Fig. 12) was developed. For ETC heat pipe solar thermal collectors, TRNSYS model was developed as shown in Fig. 13. Experimental data generation of the same collector is in progress, which will be used to validate the developed TRNSYS model.

The Indian side 2nd steering committee meeting and the Denmark side 4th steering committee meeting was organized on August 29, 2020 and December 14, 2020, respectively.

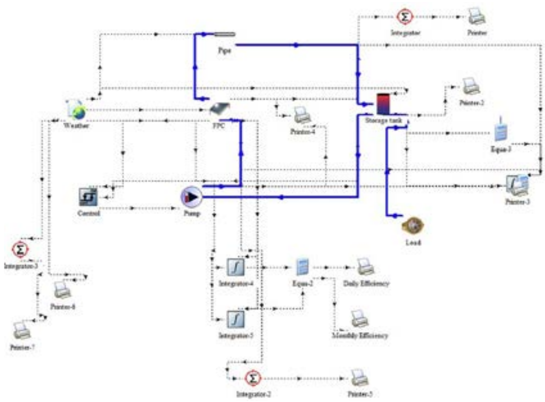


Fig. 12 TRNSYS model of FPC-based hot water system

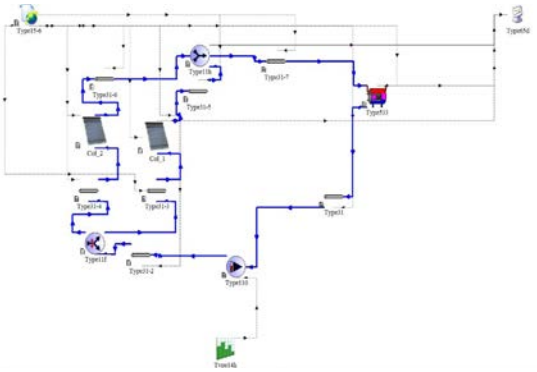


Fig. 13 TRNSYS model for ETC heat pipe solar thermal collectors

As no supplier of low capacity vapour absorption machine/chiller (VAbM) to achieve near-zero temperature in cold room was identified, it was decided to go ahead with LiBr/H_2O VabM and the specifications of a few of the system components are given in Table 4.

Table 4 System component specification

S. No.	System component	Specification details
1	Vapour absorption machine	5 TR capacity (LiBr/H_2O, hot water-driven 85 to 95°C)
2	Solar thermal collector	ETC heat pipe 20 tube collector (60 nos.)
3	Solar photovoltaic plant	12.5 kW + 15 kVA inverter
4	Back-up system biomass combustor	approx. 10 kg h^{-1} capacity
5	Nos. of cold rooms	2-3 nos. (for the case of banana ripening)

In January 2021, a company M/s New Leaf Dynamic Technologies Pvt. Ltd. was identified working on the same concept and supplying mini-cold storages with the brand name "Greenchill". They are promoting a biomass alone-driven compact cold storage of capacities 10, 15 and 20 MT. In Greenchill they used a vapour adsorption machine/chiller (VadM) having NH_3/carbon of 4 TR capacity – patented by them. With VAdM, it is possible to achieve near-zero temperature in a cold room. This makes the system useful for multipurpose activities like seasonal storage, milk chilling etc.

Site visits were made by the SPRERI team at M/s Newleaf's three installation sites at Rajkot, Jetpur and Junagadh to investigate the usefulness of the VAdM for the ongoing project. The Greenchill system was found useful. Therefore, the decision to go with VAbM has been kept on hold and discussions are in progress to adapt the VAdM in the current project. Also, the discussion with the Danish team is in progress to finalize the system components and specifications for the proposed VAdM.

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

Nano-fluid was prepared using ultra-sonicator, wherein a mixture of base fluid i.e., water and nano-particles was sonicated to break the agglomerated particles in the nano-fluid. Ultra-sonication was done at a frequency of 20 kHz at a power of 600 W. To mix diesel particulate matter (DPM) in water, the solution was stirred with a magnetic stirrer at 600 RPM for 30 min and then

(a) Instant

(b) After one month

Fig. 14 Nano-fluid with 0.1% (w/w) soot particle sonicated for 2 h. Nano-fluid was prepared for 0.1% and 0.5% w/w concentrations of soot particles. The stability of the fluid was observed visually, as shown in Fig. 14 and found stable even after six months.

Fig. 15 and Fig. 16 shows the particle size distribution of soot particles in diesel engine oil and the prepared nano-fluid. Fig. 15 shows that most of the particles in diesel engine oil are actually nano-particles below 45 nm. Still, some bigger size particles are also seen in the oil, which need to be filtered from the engine oil before using it for nano-fluid preparation. Fig. 16 indicates that the nano-particle size in nano-fluid is below 45 nm. Further nano-fluid preparation and characterization work is in progress.

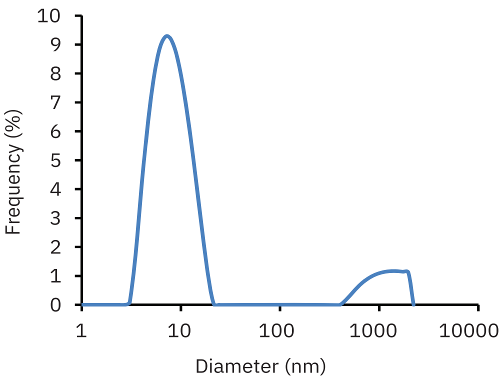


Fig. 15 Particle size distribution analysis of diesel engine oil

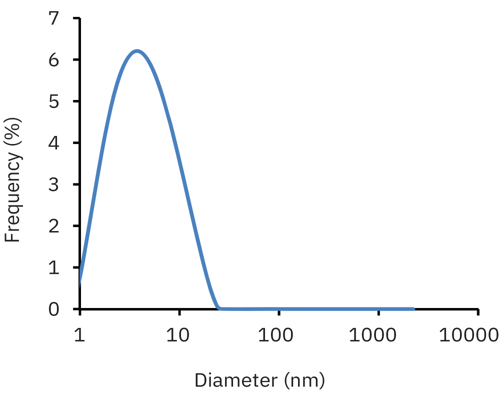


Fig. 16 Particle size distribution analysis of soot particle based nano-fluid

Regional Test Centre for Solar Devices

The testing of all received flat plate collectors (FPC) samples were completed, reports were issued and sent to the respective customers. The testing of FPC and solar box cooker (SBC) as per NABL and BIS has been discontinued at SPRERI. However, non-NABL and BIS testing of ETC-HWS (as per IS 16368:2015) is being continued. To make the testing, a self-sustaining activity, the testing fees were revised and raised as shown in Table 5.

Table 5 Revised rates for solar hot water testing

Description	Capacity (Lpd)	Prevailing test fee per sample (Rs.)	Revised test fees per sample (Rs.)
Evacuated tube based solar water heating system	Up to 100	20,000/-	50,000/-
	101 to 200	23,000/-	55,000/-
	201 to 300	25,000/-	60,000/-

The centre's BIS certification and NABL accreditation for testing solar devices was valid till August 15, 2020 & November 29, 2020, respectively. Due to the closure of the RTC Test Centre, renewal applications were not sent. To revive and upgrade the test facility for full adaption of the test standards IS 16542-16544:2016 and 16368:2015 followed by NABL and BIS accreditation, two proposals were submitted to MNRE on February 8, 2021 for a one-time grant under lab policy. During the period, the test centre has tested one evacuated tube based hot water system and received 5 samples for reflectivity test.

2.1 Liquid, Gaseous & Solid Bio-fuel

The next generation bio-fuel (bio-methanol) from bio-gas by methanotrophs

Methane is one of the cheapest carbon sources that can be easily metabolized by methane oxidizing microbes to produce bio-fuels and other value-added products. Bio-gas contains around 30-70% of methane which can be utilized by methanotrophs via central carbon cycle to produce methanol. With this backdrop, the proposed project therefore, aims at isolation of suitable bio-catalysts with a potential to produce methanol from methane. Experiments are therefore set-up for isolation of methane oxidizing bacteria from different sources such as cow dung slurry, anaerobic digested sludge and paddy field soil. A potential strain isolated from cow dung slurry was identified as *Methylobacillus flagellates*. The phylogenetic tree shown its similarity with other methanotrophic strains such as *Methylobacillus arboreus and Methylobacillus glycogenes* (Fig. 17). The fermentation batch is carried out in 100 mL serum bottles containing NMS2 medium with pure methane (50% v/v) as the sole carbon source. The broth from fermentation samples were analyzed in GC with FID detector which has shown production of methanol in the fermentation broth equivalent to 0.15% (w/v).

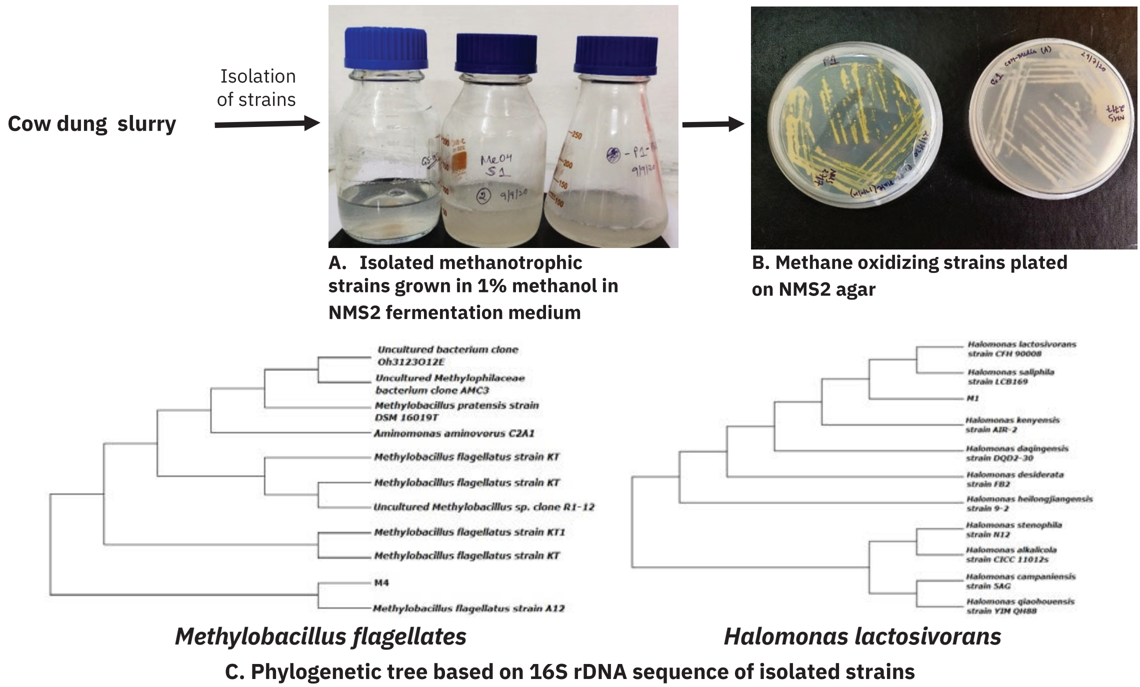


Fig. 17 Schematic representation of methanol production from methane oxidizing microbes

3rd generation bio-diesel from micro-algae

Response surface methodology (RSM) based on central composite design was applied for optimization of parameters which affect the efficiency of transesterification reaction and algal bio-diesel yield viz. reaction time, temperature, catalyst concentration, oil to methanol ratio. Maximum bio-diesel yield obtained through RSM was found to be 36% (w/w) obtained at the optimum condition of 135 min reaction time, 80°C temperature, oil to methanol ratio of 1:7 and catalyst amount of 3.5%. In the up-scale reactor of 5 L capacity, maximum conversion efficiency of 95% (w/w) of crude bio-diesel was obtained, while decolorisation and purification through montmorillonite clay K10 led to 38.9% conversion efficiency. A schematic representation of bio-diesel production from micro-algae is shown in Fig. 18. Physico-chemical characterization of micro-algal bio-diesel was performed as per standards and values are shown in Table 6.

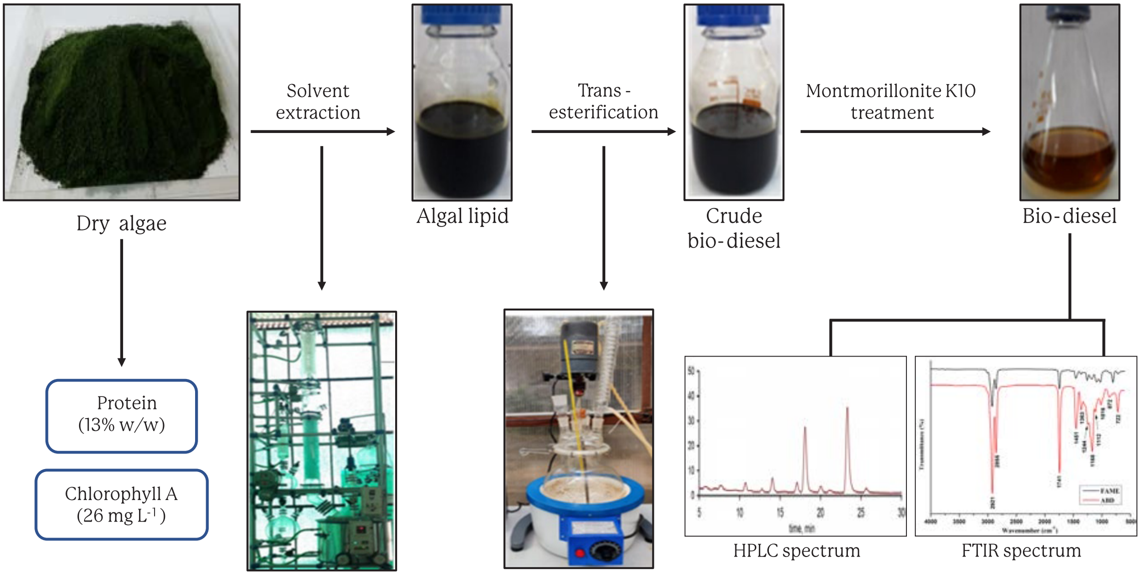


Fig. 18 Schematic representation of bio-diesel production from micro-algae

Table 6: Micro-algal bio-diesel parameters

Parameters	Result	Standard value
Carbon residue (% by mass)	0.03	0.05 (ASTM D4530)
Cetane number	48	47 (ASTM D613)
Acid value (mg KOH g^{-1})	1.06	0.50 (ASTM D664)
Sulphur (as S) (mg kg^{-1})	24.12	50 (ASTM D4294)
Total contamination (mg kg^{-1})	23.02	24 (EN12662)
Pour point (°C)	8.0	6-15 (ASTM D97)
Ash (% by mass)	-	0.01 (ASTM D482)
Cloud point (°C)	12.0	8 -17 (ASTM D 2500)
Calorific value (kcal kg^{-1})	6542	NA
Distillation temperature (°C)	90% distillation at 360	90% (ASTM D86)
Fire point (°C)	59	NA
Copper strip corrosion (3 h at 100°C)	1	1 (EN ISO 2160)
Iodine value (g iodine 100 g^{-1} (°C)	27	120 (EN 14110)
Density (kg m^{-3})	868	860-900 (EN 14214)
Viscosity (mm^2 s^{-1})	6.3	1.9-6.0 (ASTM D445)

A techno-economic analysis was performed for a dairy effluent based process for micro-algae cultivation and its conversion into bio-diesel. A techno-economic study was performed for two different scenarios. In the first scenario, the revenue generating products considered were only micro-algae and recovered water obtained from dairy effluent. While in the second scenario, the dairy effluent grown micro-algae was used for bio-diesel production and therefore, revenue generating products considered in the second scenario were bio-diesel, glycerol, delipidified micro-algae and recovered water. Techno-economic analysis was performed for different categories of dairy effluent treatment plants i.e., 0.25, 0.5 and 1.0 MLD (Table 7). It was found that the scenario in which micro-algae was being converted to bio-diesel and other products was not feasible at the current values of lipid content and bio-diesel conversion ratio. However, the scenario, where micro-algae was the only major product and can be made commercially available to different users based on their requirements, was feasible with payback period of less than a year. Therefore, improvements in the existing parameters of micro-algae growth, lipid content and bio-diesel conversion ratio is much needed in order to make the micro-algal bio-refinery model feasible and sustainable in the long run.

Table 7: Techno-economic feasibility of the two scenario's worked out at SPRERI

Details	Wastewater to micro-algae			Micro-algal bio-diesel		
Capacity of micro-algae plant (MLD)	0.25	0.5	1.0	0.25	0.5	1.0
Annual capacity of water treatment (kg)	82,500	1,65,000	3,30,000	82,500	1,65,000	3,30,000
Total investment cost (TIC)	37,06,000	69,42,000	1,10,35,000	42,06,000	77,92,000	1,25,35,000
Total operational cost (TOC)	14,40,716	29,97,730	48,33,843	45,72,901	79,96,028	1,31,56,405
Savings on chemicals and electricity from aerobic system	22,52,250	36,03,600	57,65,760	22,52,250	36,03,600	57,65,760
Total revenue (TR*)	67,07,250	1,25,13,600	2,35,85,760	47,29,550	85,58,200	1,56,74,960
Net savings (TR-TOC)	52,66,534	95,15,870	1,87,51,917	1,56,648	5,62,172	25,18,555
Payback (Years)	0.70	0.73	0.59	26.84	13.86	4.97

*Products in wastewater to micro-algae: micro-algae recycled water

*Products in micro-algae to bio-diesel: bio-diesel, delipidified micro-algae, glycerol, recycled water

Conversion of wet organic fraction of municipal solid waste (MSW) to useful energy fuels (bio-gas)

Long duration bio-methanation studies were continued for one more year to confirm the findings reported earlier using in-house fabricated laboratory-scale anaerobic hybrid reactor (AHR) at both meso and thermophilic temperatures using the organic leachate of MSW as an influent. The reactors were packed with natural and synthetic media i.e., pumice stone & pvc waste material, respectively. Performance monitoring was carried out at 2 different HRT's viz. 5 & 3 d. Leachate COD was in the range 30-35 g L^{-1}. Inlet COD maintained was 5 g L^{-1}. After steady state conditions, the bio-gas production at 5 & 3 d HRT was found to be 68, 60 and 83, 75 L kg^{-1} material, respectively. 22-25% higher gas production was achieved at 50°C. The pH of the reactors after anaerobic digestion was within the optimum pH range of 7.21-7.42. VFA: alkalinity ratio remained within the stability range of <0.4. Methane content was in the range of 65-69 and 73%, respectively. Composting studies were carried out using the solid residue generated during the dewatering process of wet organic fraction of MSW. Mature compost was produced within 30 days. The produced compost has carbon-23.28%, nitrogen-3.27%, phosphorus-1.62% and potassium-5.28%.

Solid fuel production from mixed agro-residual biomass (pellets)

In continuation of previous years research, to improve the quality of pellets in terms of mechanical strength, different biomass blends and synthetic and waste biomass materials as binders were tried. Rice straw (RS) pellets of 8 mm die, are being made with the addition of locally available agro-residual biomass namely cotton stalk (CS), wheat straw (WS), groundnut shell (GNS), banana stem (BS) in 3 different ratios (100; 75:25; 50:50; 25:75). Pellets were of 8 mm die, also produced from RS mixed with starch, glycerol, cooked potato waste (CPW), vegetable market waste (VMW), water hyacinth (WH) and cattle dung (CD) etc. (Fig. 19). Pellets were produced using a commercially available 70-80 kg h^{-1} capacity rotary drum type pelletizer. The prepared pellets were analyzed for their fuel properties; i.e., calorific value (CV), bulk density, durability, proximate and elemental compositions followed standard protocols. The produced pellets were tested as a fuel using a forced-draft domestic size cookstove for thermal efficiency. Thermal efficiency was found to be in the range of 27 to 36%. CV and durability of the produced pellets was in the range of 13 to 17 MJ kg^{-1} & 95-99%, respectively. Out of the tested ratios, 75:25 ratio was found to be best in terms of CV, bulk density and durability. Preliminary production cost of the blended pellets has been carried out by considering the fixed cost and O&M cost for RS:CS; RS:WS; RS:GNS; RS:BS, RS:starch and RS with waste materials. The O&M cost considered the labour, energy input, consumables and biomass cost. It also considered the transportation, packing charges, maintenance cost of the pelleting machine etc. The cost of the pellets was ranging from Rs. 7.9 to 8.9 per kg^{-1}.

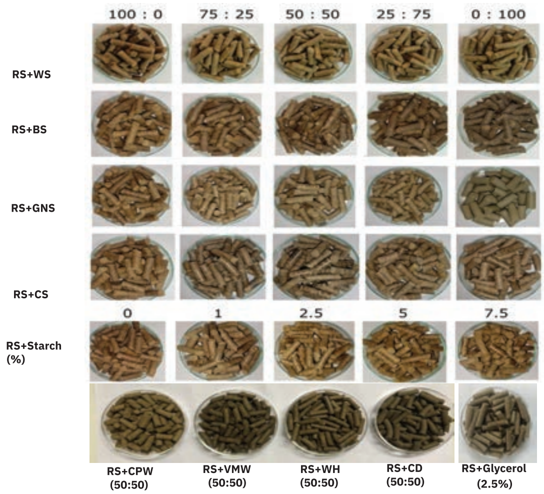


Fig. 19 Biomass pellets using different blends and binders

2.2 Value-added Products and its Application

Valorization of NADES extracted lignin for the development of nano-composites (nano-fiber and nano-gel)

Lignin nano-particles were synthesized by two different methods viz. anti-solvent method and dialysis method using lignin obtained through NADES pre-treatment of 05 different agro-residues i.e., RS, WS, CS, sugarcane bagasse (SB) and sawdust (SD), while indulin derived nano-particles were used as control for comparison. In anti-solvent method, filtrated solutions were separately added drop-wise into milli-Q water with constant magnetic stirring. After continuous stirring, the obtained suspensions were centrifuged to remove aggregates, followed by lyophilization to obtain a dry powder of nano-particles. Under the dialysis method, the filtered lignin solutions were transferred into a dialysis tube which were placed in excess amount of Milli-Q-water (replaced after every half an hour intervals) for over 3 h under slow stirring. Further, suspensions were collected by centrifugation followed by lyophilization to obtain a dry powder of lignin nano-particles. Minimum size of lignin nano-particles obtained through anti-solvent method and dialysis method was 99 nm and 73 nm with WS & RS, respectively. Nano-particles were further characterized through UV-Vis spectroscopy, FTIR, SEM and TEM. These nano-particles were then employed for the synthesis of lignin nano-fibers through electrospinning method. Different polymers viz. polyvinyl alcohol (PVA), polylactic acid (PLA), polyvinyl propylene (PVP) were used for synthesis of nano-fibers and through SEM analysis, PVA was found to be the most suitable polymer. Fig. 20 shows the process of lignin nano-fiber synthesis through electrospinning process.

Lignin nano-gel - Lignin nano-particles synthesized have found applications in synthesis of nano-gel through UV curing method. A UV curing cabinet was designed and developed for synthesising nano-gel using polymers (Fig. 21). Nano-gels were prepared by UV-initiated polymerization of aqueous solutions of acrylamide as polymer and N,N-methylene bis (acrylamide) as cross-linker. Acrylamide and bis-acrylamide were dissolved in water. Irgacure was added as the photo-initiator. The mixture was exposed to UV light with the 22 W UV dosage till the gel formed and time recorded as response. Different concentrations of acrylamide, bis-acrylamide and irgacure were optimized through RSM and most optimized combination for nano-gel has been found with 8.58% of acrylamide, 0.8% of bis-acrylamide, 1% of irgacure and 15 min of gelling time. The gel was physico-chemically analyzed through FTIR, SEM and UTM etc. Lignin nano-particles incorporated gels were synthesized and these gels were found to have applications in water retention, bio-medical and industrial applications.

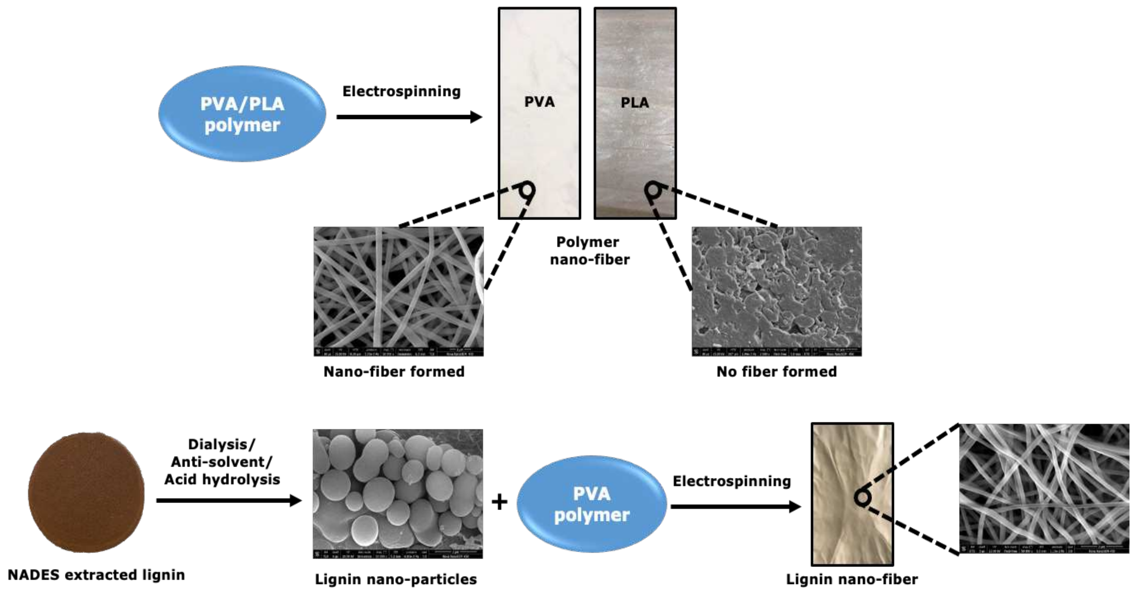


Fig. 20 Schematic of lignin nano-fiber synthesis

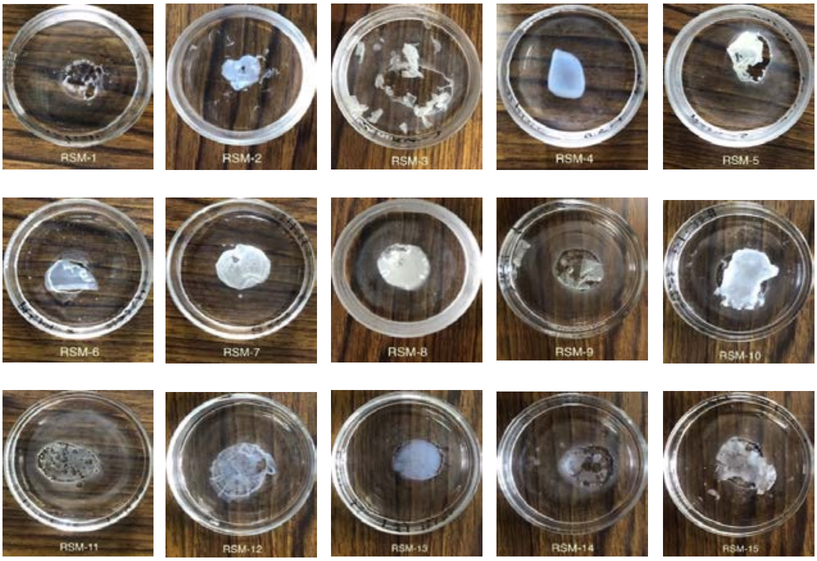


Fig. 21 Optimization studies of nano-gels through RSM

Algal biomass to value-added byproducts (aquafeed, pigments & proteins)

In-house cultivated micro-algae in dairy effluent was used as an aquaculture feed supplement by feeding it to *Clarias gariepinus* fish and compared with commercial aqua feed. Body weight measurements of fish were taken every fortnight. The overall changes in the body weight were marginally different. However, lower protein, lipid and glycogen accumulation was observed in algae fed fish (9.03±0.08, 20.78±0.5 and 5.24 mg g^{-1}) as compared to commercial feed fish (13.20±0.13, 24.02±0.06 and 25.21±0.24 mg g^{-1}), respectively. This is possibly because the feeder *Clarias gariepinus* is a carnivore while the feed i.e., micro-algae is of plant origin. Micro-algae were also applied for protein and pigment extraction for developing it as a source of multiple value-added products. Proteins were extracted and precipitated using three-phase partitioning using tert-butanol as solvent and 30% ammonium sulphate solution. Pigments were extracted from microwave and untreated micro-algae through different methods viz. direct solvent extraction, pre-heated solvent extraction method and mechanical grinding method. Protein content of 13±1.5% (w/w) of micro-algae biomass was obtained. Pigment concentration in micro-algae analyzed through spectrophotometric study found that maximum pigment was extracted through mechanical treatment method, which was found to be around 26 and 22 mg L^{-1} for microwave treated and untreated micro-algae, respectively.

Lipid extracted micro-algae biomass residues (LMBR) to bio-hydrogen & aqua feed

LMBRs are residues left after vigorous lipid extraction process of raw micro-algae biomass which reduces the cellulose content as compared to raw algae biomass. Pre-treated and un-treated LMBR revealed that it contains only 3% cellulose and 8% hemicellulose which after acid or alkali treatment reduced to 2% and 7%, respectively. This is in accordance with the HPLC analysis of the pre-treated LMBR (liquid part) which showed glucose content of 1.5%. The sugars released after thermochemical pre-treatment is further characterized by total carbohydrate analysis and FTIR. The pre-treated slurry is utilized for batch fermentation using various inoculums including cow dung (CD) slurry, dairy sludge (DS) and RS compost at two temperatures 37 and 50°C. The maximum hydrogen content of 40% v/v was achieved with a mixed inoculum of DS and RS compost at 50°C. This was confirmed by GC analysis of the headspace gas as shown below (Fig. 22). Initial characterization of LMBR is done to evaluate its potential to be used as aqua feed and bio-fertilizer. Elemental analysis of LMBR revealed the presence of essential elements necessary for aqua feed within the required range, with phosphorus (250 mg L^{-1}), calcium (448 mg L^{-1}), potassium (75 mg L^{-1}), magnesium (72 mg L^{-1}) as the major components along with other trace elements.

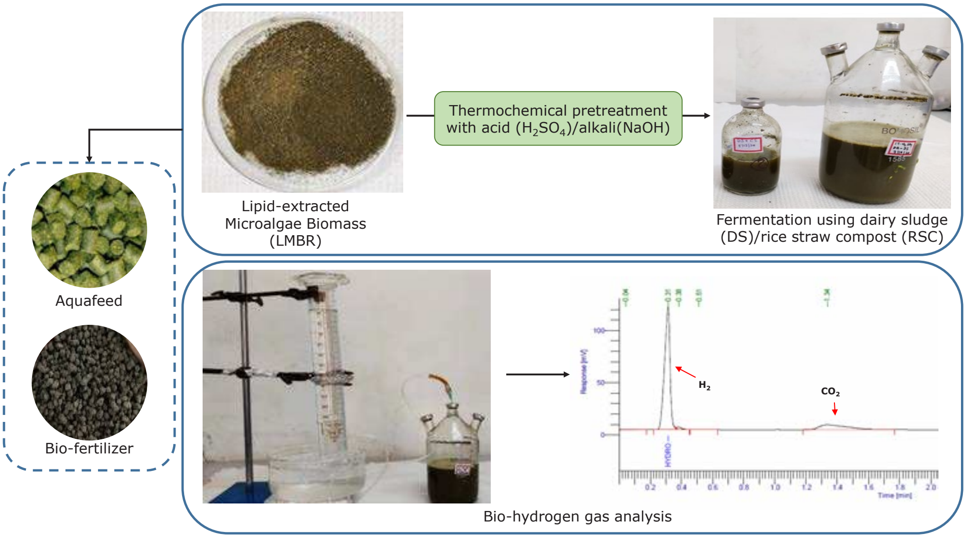


Fig. 22 Schematic representation of bio-hydrogen production from LMBR

Micro-crystalline cellulose (MCC) to industrially important furfural derivatives

Transformation of RS and BS into value-added materials, nano-materials and chemicals not only utilizes the redundant biomass but also provides the solution of burning the biomass that creates the huge pollution in air. Cellulose is the most prominent part presented in the biomass which can be converted into various useful materials such as MCC, cellulose nano-crystals (CNC), and industrially important chemicals such as sorbitol, xylitol, furfurals, γ-valerolactone, levilunic acid, etc. MCC is one of the major products of cellulose which is obtained from partial depolymerization process. These products have huge importance in the pharmaceutical, food, paper, cosmetic, and fuel industries.

Alkali followed by bleaching treatment was explored to obtain the high purity cellulose from RS and BS wherein different concentration of NaOH and sodium chlorite at substrate to moisture ratio were evaluated at room temperature and under microwave irradiation (Fig. 23). The removal of more than 85% lignin from biomass was achieved at 48 h and 20 min at room temperature and microwave irradiation. Further the recovered cellulose was hydrolyzed with 10% H_2SO_4 to obtain the MCC which was characterized with SEM, TEM, FTIR, XRD, XRF, CHN and particle size analysis. Results showed that the MCC obtained from BS and RS were 68.38 nm and 402.33 nm based on the particle size analysis. To depolymerize the MCC, more than 17 metal catalysts were prepared using different metal salts via impregnation method. Reactions were also carried out to obtain the sugar, sugar alcohol and furfural derivatives.

Fig. 23 MCC prepared from RS and BS

2.3. Decomposition of RS with selected microbial consortia

Composting has been considered an attractive alternative for disposing organic wastes due to less environmental pollution and the final product suitable for a sustainable strategy. Microorganisms as the driving the force play the pivotal role in degrading organic matter during the composting process. In a trial to hasten the compost maturation process and to improve the quality of compost, the screened and isolated bacterial and fungal strains were mixed with rice straw.

The temperature pattern showed a rapid increase from the initial mesophilic phase to the thermophilic phase where it reached up to 68°C in the middle, 55°C at the top and 46°C at the bottom after three days of composting process. The increase in compost temperature is caused by the heat generated from decomposition of organic matter by the activity of aerobic microorganisms that is important at the beginning of the composting process. Interestingly, the piles have longer time above 58°C of about 15 consecutive days which is necessary to kill the indigenous pathogens. During the study it was noticed, that the carbon loss due to the emitting of carbon dioxide as a result of microbial metabolic activities and decomposition progress. Total nitrogen content was reduced in the early stage of composting and then a gradual increase was achieved to the end of the process. The late increase in nitrogen content may be due to the loss of dry mass in terms of carbon loss. The decrease in carbon to nitrogen ratio less than 20 in the current study indicates that the degree of humification of organic matter and considered one of the most important parameters to evaluate the maturity of compost product. The degree of compost maturity can be assessed by physical parameters such as color and odor. A gradual darkening of the compost material was noticed by naked eye during the composting process. The color of the final product after sufficient period of maturation was dark brown. The moisture content (%) and the bulk density in the matured compost were ranged 33.5-40.5 and 516-583 kg m^{-3}, respectively. The final product had C/N ratio of 17.18; potash-5.42% and phosphorus-0.717%.

3.1 Gasification

Introduction of fluidized bed gasification (FBG) system in poha making industries for improved efficiency and working environment

As mentioned in earlier reports, most of the poha-making industries are located in the rural areas of the state and the country. Thermal energy requirement in such industries for roasting of soaked paddies and/or the flaked products is mostly carried out *via.* the conventional process of SD combustion. This not only reduces the efficiency of the roasting application but also deteriorates the working atmosphere. Therefore, SPRERI has designed and developed an automated FBG unit (100 kg h^{-1} feeding rate) to improve the efficiency and environmental aspects of the roaster in the poha-making industry. The developed gasification unit works on the conventional fuel of the industry, i.e., SD. Considering the requirements of controlling the process and providing convenience to the users, the FBG system was automated. In addition, further improvements; i.e., introduction of the by-pass line, tar collector and the combined ashbin between both the cyclones were made (Fig. 24). Such modifications were made to improve the operation and modification cycles of the system. The developed system was rigorously tested with long-run trials using SD as a fuel.

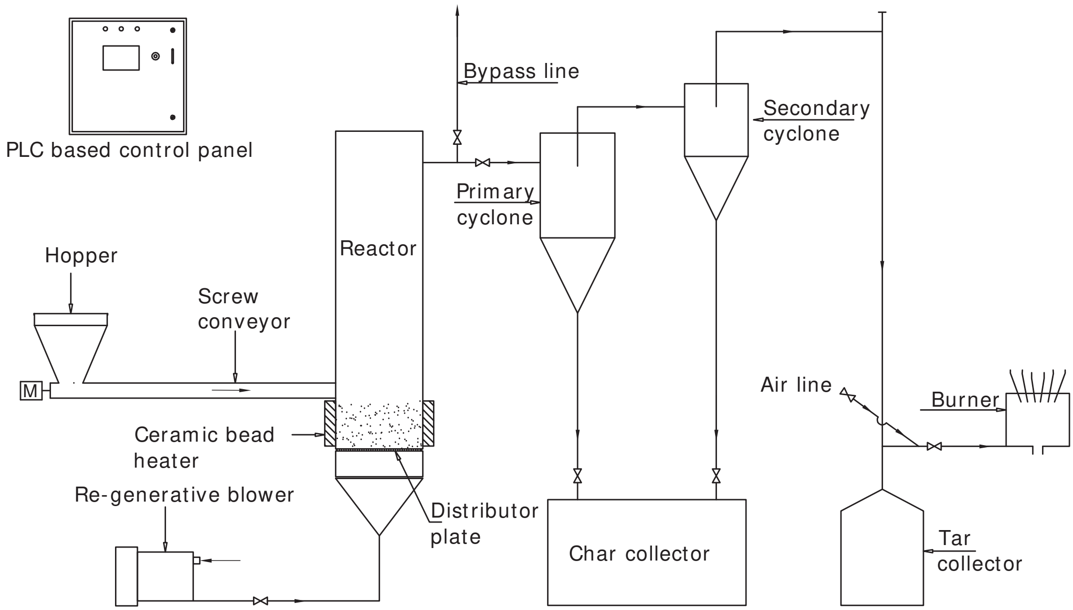


Fig. 24 The modified FBG system for the poha industry with insulation and modified gas line

During each experiment, the temperature profile for the reactor (temperature at sand bend, free board entry, free board middle and free board top) and at the cyclone inlet was recorded. The profile was stable and reproduced in every experiment (Fig. 25). From the temperature profile it can be seen that the temperature of the sand bed of the reactor was constantly in the range of 700-800°C. The obtained temperature range is ideal for the gasification process to generate hydrogen rich syn-gas. Along with this, the gas temperature at the outlet of the reactor (cyclone inlet) was constantly above 400°C. It ensures the minimum tar condensation inside the pipeline.

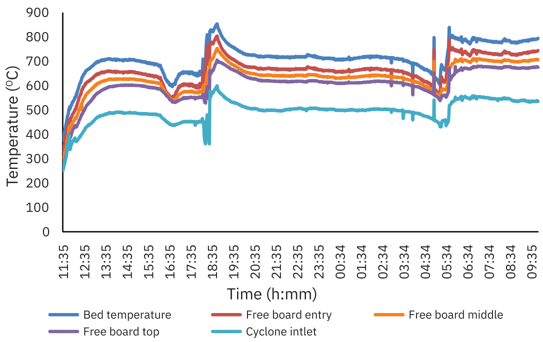


Fig. 25 Time-based temperature profile of the system during the long-duration trial

Post system development and after long-run trials, two operators of the first beneficiary were trained in operation and maintenance of the system. The team also visited the site of the beneficiary for mutual finalization of the location to install the system and to initiate the civil work process. The introduction and retro-fitting of the FBG is in progress.

3.2 Pyrolysis

Continuous pilot-scale intermediate pyrolysis system

To make the feeding of fibrous biomass trouble-free and to make the fuel feeding system flexible for any loose biomass, a few modifications were made in the existing system (Fig. 26). The inclined screw conveyor was made horizontal for easy feeding of the biomass.

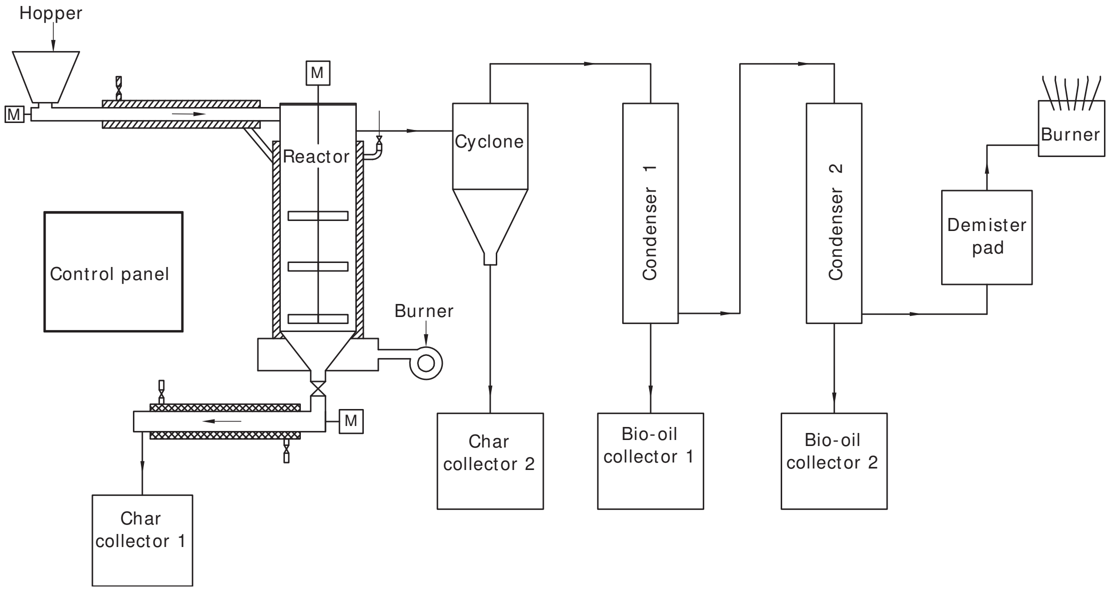


Fig. 26 Schematic arrangement of modified pilot-scale continuous pyrolysis system

Post modification, the system was tested and experiments were carried out with three different biomass, i.e., SD, GNS and CS for bio-oil and bio-char production for the different requirements in the division. The obtained bio-char (25-30 wt.% product yield) was densified into the pellet form and tested in a forced-draft cookstove. The bio-char was also used for its conversion into activated carbon using chemical activation. On the other hand, the produced bio-oil (35-43 wt.%) was blended with the furnace oil to test and optimize the bio-oil based burner designed and developed by the team. The blending of the bio-oil was carried out in the raw form of the liquid product i.e., without separation of the aqueous phase from the bio-oil.

Before utilizing the pyrolysis products in the above-mentioned applications, each product was characterized in detail to measure the quality of the pyrolysis process using the modified system. The stored and prepared bio-oil samples were subjected to NMRs (1H & 13C), CHNO, GC-MS, FT-IR and TGA along with the different physical properties; i.e., pH, CV, viscosity, density, solid content and water content. At the same time, the bio-char samples were characterized *via*. FT-IR, SEM, CHNSO, bulk density, CV and proximate analysis. In addition, the third product of the pyrolysis, i.e., pyro-gas was characterized during the trials using the gas chromatograph.

Fast pyrolysis

A fluidized bed fast pyrolysis system has been designed and developed at SPRERI (capacity: 8 kg h^{-1}) (Fig. 27). Ceramic bead type external heaters are provided to match the temperature requirements of the process. SD, GNS and CS were used as raw material for the fast pyrolysis experiment. Pre-processing of the biomass was done by sizing and sieving it to the range of 0.5–4 mm followed by drying at 100°C to bring the moisture content to 2–3 wt.%. Fe_2O_3 and CaO being widely available and having low cost were selected as catalysts for the catalytic fast pyrolysis experiments. The catalyst was first sieved and dried at 120°C for 2 h in a hot air oven to remove the moisture and kept in a desiccator. 2 wt.% Fe_2O_3, and CaO catalyst were mixed with the sand bed for experimental trials.

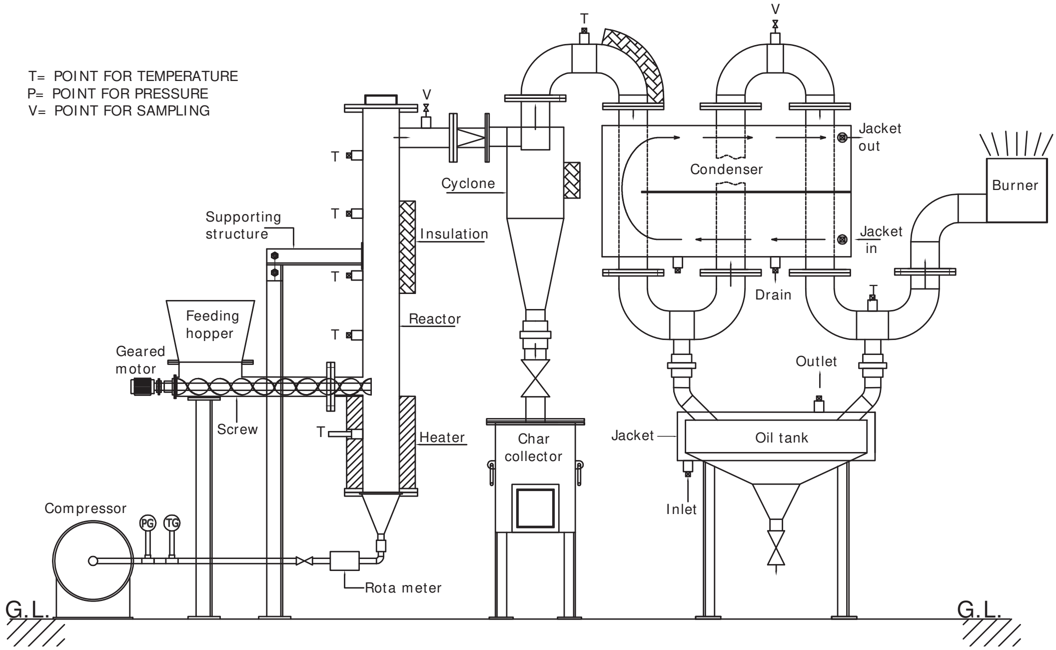


Fig. 27 Schematic of fast pyrolysis system

The initial trials were conducted at an 8 kg h^{-1} feeding rate at a temperature of 550°C for 2 h. Bio-oil samples were characterized for FT-IR, GC-MS, ^{1}H NMR, and ^{13}C NMR. The bio-oil yield was observed to be in the range of ~27-32 wt.% (without catalyst) and ~32-37 wt.% (with Fe_2O_3 and CaO catalyst) (Table 8). The organic and water content in the produced bio-oil was observed to be in the range of ~21 wt.% & ~79 wt.% in non-catalytic mode and ~27 wt.% & ~73 wt.% in catalytic mode, respectively. The quality of bio-oil observed more appropriate in the catalytic mode in comparison to the non-catalytic mode.

Table 8 Average product yield obtained during fast pyrolysis (non-catalytic & catalytic) experiments using SD, GNS and CS

Non-catalytic mode			
Feedstock	Average yield (wt.%)		
	Bio-oil	Bio-char	Pyro-gas
SD	36.76	12.54	50.70
GNS	32.54	13.76	53.70
CS	33.65	14.11	52.24
Catalytic mode			
SD (Fe_2O_3)	31.66	13.32	55.02
SD (CaO)	30.45	13.11	56.44
GNS (Fe_2O_3)	28.11	15.12	56.77
GNS (CaO)	27.22	15.01	57.77
CS (Fe_2O_3)	28.83	14.98	56.19
CS (CaO)	27.61	14.34	58.05

3.3 Combustion

Refinement of bio-oil based burner for thermal application

The developed bio-oil based burner was modified to improve the flame stability and ultimately the system performance. Previously, during the feasibility testing of the burner configuration, axial air supply was provided to the fuel.

In the latest modifications, for proper mixing of the fuel and air, two different configurations were tested. In the first configuration, a distributor plate was used with the axial flow of air, and in the second one, a tangential air supply was tested. Between these two configurations, tangential air supply has shown a more stable flame with proper air-fuel mixing (Fig. 28).

In the modified configuration, 5 wt.% blend of bio-oil and furnace oil was tested for three times for a 3 h duration at 30–35 LPH for flame stability. After the stability testing, a combustion chamber (~2 m^3 volume) was developed along with the stack (height:3.6 m) with the provision of ports for the emission measurement (Fig. 29). For each trial, the fuel (furnace oil and respective blends of bio-oil and furnace oil) was pre-heated (70-90°C) to reduce the viscosity of the furnace oil. In the case of any blend as a fuel, stirring was also introduced to mix bio-oil and furnace oil properly. After achieving the stable flame during all trials, the flame temperatures were measured with the 'K-type' thermocouple. The emission profiles were recorded using the flue gas analyzer (Testo-350).

Fig. 28 Modified bio-oil based burner with tangential air inlet

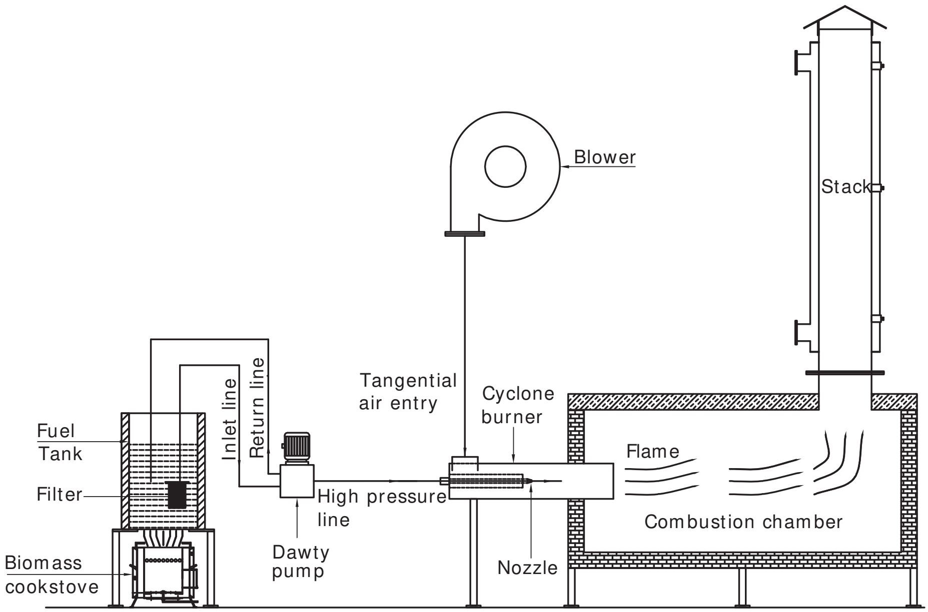


Fig. 29 Schematic arrangement of the modified bio-oil based burner assembly attached with the developed combustion chamber

Different blends of bio-oil and furnace oil (10 wt.% to 20 wt.%) were successfully tested in the apparatus to see the combustion behaviour and the emission profile development. Details of the flame temperature and emission profiles are given below (Table 9). For emission profile, CO, CO_2, NOx and SO_x were observed. In addition, oxygen was also considered to determine the effect of the excess air over the combustion process.

Table 9: Flame temperature along with the emission profile for different blends at different equivalence ratios

Blend (wt.%)	ER	O_2 (%)	CO (ppm)	CO_2 (%)	NO (ppm)	SO_2 (ppm)	SPM (mg m^{-3})	Flame temp (°C)
FO (100)	1.17	11.81	571.75	7.50	88.25	785.75	228.59	1083
	1.46	11.75	589.21	7.29	104.18	792.13	92.99	985
	1.65	11.12	320.36	7.43	114.87	814.38	54.36	1326
	1.95	12.16	515.89	6.71	102.50	746.75	72.61	1245
BO:FO (10:90)	1.13	4.22	1069.31	13.11	89.28	1232.38	71.42	950
	1.41	11.32	206.88	7.36	110.88	668.75	24.35	1148
	1.59	10.88	103.00	7.90	120.83	727.84	50.37	1096
	1.88	10.39	47.14	8.20	137.12	742.38	36.81	1008
BO:FO (20:80)	1.04	8.72	338.69	9.45	100.16	1034.51	627.60	911
	1.30	11.34	151.89	7.45	115.25	793.63	439.93	946
	1.47	11.46	206.00	7.53	115.12	773.63	327.79	921
	1.73	10.91	112.60	8.13	132.00	853.51	80.00	914

The emission study showed that with increasing equivalence ratio (ER); CO emission reduced consistently as air to fuel ratio improved. The trend of the NO emission is increased the bio-oil content in the blend. The higher temperature of the combustion chamber and availability of the nitrogen containing compounds in the bio-oil results in the increased NO_x in the flue gases. The PM emission was also increased with increased bio-oil content in the blend, due to high SPM content and polymerization effect of the bio-oil.

3.4 Value-added Products from Agro-residues

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

Initially, the experiments on bench-scale (capacity: 50 g; reactor volume: 0.002 m^3) for activated carbon generation from GNS were conducted. In order to examine the feasibility of the process, further experiments were performed on a higher scale (capacity: 250 g; reactor volume: 0.009 m^3) with GNS, SD and CS, respectively using $ZnCl_2$, H_3PO_4 and KOH as activating agents in 1:1 impregnation ratio at 550°C temperature in batch mode. The experiments were conducted in an inert atmosphere with 100 mL min^{-1} nitrogen flow.

After obtaining the successful results using raw agro-residues as a feedstock, the activation of the bio-chars generated from GNS, SD and CS were also carried out. The particle size of the bio-char was kept in the range of 0.8-2.0 mm. Similar activating agents ($ZnCl_2$, KOH and H_3PO_4) were used for the activation of the bio-char samples. The impregnated (impregnation ratio 1:1) samples were kept for overnight drying at 100°C temperature. The above-mentioned activation process (550°C process temperature, 100 mL min^{-1} nitrogen flow rate) was performed for the activation of the bio-char samples. Post-activation, the activated samples were washed using DI water and dried at 100°C.

The yield of the activated carbon after processing 250 g of GNS, SD and CS char samples was found in the range of 85-90 wt.%. The generated activated samples were characterized for the BET analysis (Table 10). Methylene Blue numbers (MBn) were also determined for activated carbon samples prepared from GNS, SD and CS char using $ZnCl_2$, H_3PO_4, and KOH as activating agents. Average results are reported in Table 10. The results indicates higher adsorption using $ZnCl_2$ as an activating agent. It also observed that the, adsorption capacity is directly proportional to the surface area of the activated sample (Table 10).

Table 10 MBn for the activated carbon samples prepared from the char of GNS, SD and CS using different activating agents

S. No.	Sample name	ABS (m g^{-1})	MBn (mg g^{-1})	Surface area ($m^2 g^{-1}$)
1	GNS-C_$ZnCl_2$	9.94	198.8	561.67
2	GNS-C_H_3PO_4	9.75	195.0	271.78
3	GNS-C_KOH	9.67	193.4	208.34
4	SD-C_ $ZnCl_2$	9.81	196.2	400.83
5	CS-C_ $ZnCl_2$	9.89	197.8	534.63

Depending on the results obtained for the chemical activation of the agro-residues and bio-char of the agro-residues, a pilot-scale activation system is conceptualized. Fabrication of the pilot-scale activation system (capacity: 5 kg) is in progress. The schematic arrangement of the system is shown in Fig. 30.

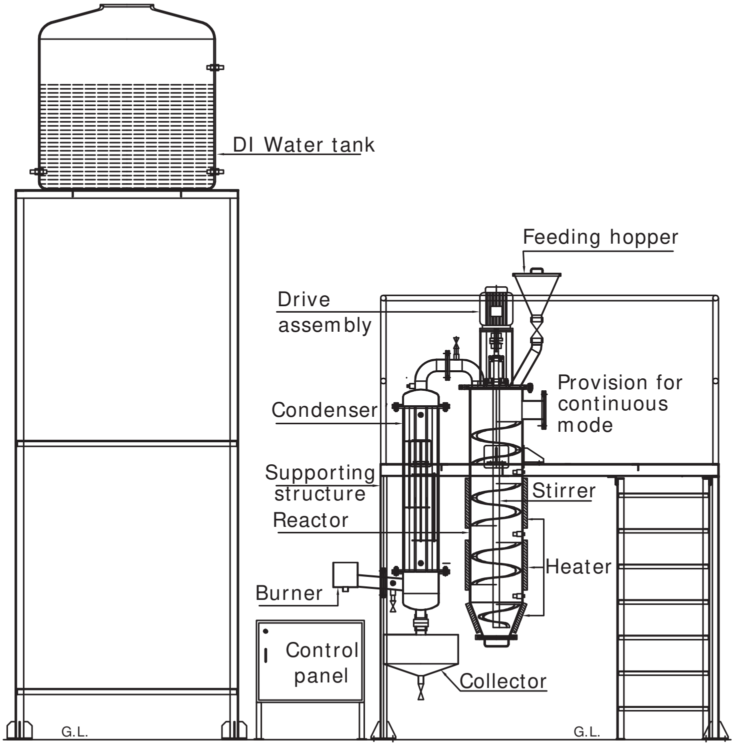


Fig. 30 Schematic diagram of the reactor for the production of activated carbon from agro-residues

Production, characterization and demonstration of char pellets as a fuel in forced-draft cookstove

Over the last few decades, pyrolysed char has attracted global attention due to its high potential use in a wide range of areas such as wastewater treatment, as a catalyst, for activated carbon synthesis, water purification, CO_2 capture, energy storage, and soil amelioration etc. However, its application as a fuel is still a less explored research arena. Due to severe de-volatization, pyrolysis increases the porosity, brittleness and ultimately the grind-ability of the bio-char. In order to explore clean working experience, the loose bio-char (CV: 23 MJ kg^{-1}) obtained from pyrolysis of GNS was densified to pellets of 6 mm size to evaluate its energy potential (Fig. 31). The bio-char pellets (durability: ~95%) were prepared using a lab-scale pelletization unit with tea waste as an additive (20 wt.%).

a) Bio-char b) Tea waste c) Char pellets

Fig. 31 (a) Bio-char obtained from the pyrolysis of GNS (b) Tea waste (and (c) Char pellets

The production cost of GNS bio-char pellets is Rs. 26.42 kg^{-1}. The cost has been calculated by considering three major components inclusive of working capital; *viz.* pre-processing cost of raw material (grinding and screening), pyrolysis cost, and pelletization cost, excluding the cost of manpower.

Performance evaluation of the produced char pellets as a fuel was tested in a forced-draft cookstove. The complete combustion of the pellets in the cookstove suggests its suitability as a fuel for thermal applications.

Training Programmes and Awareness Creation

Due to COVID-19 pandemic, training programmes were organized virtually by different divisions of SPRERI and E-certificates were issued to the participants.

- Bio-conversion technology division had organised a virtual two day training programme on 'Analytical Instruments and Techniques' on 16-17 February, 2021. This program aimed to provide basic working principles of analytical instruments cum techniques commonly used in biotech laboratories. A total of 100 participants were registered for this training program, which included graduates, postgraduates, PhD scholars and faculty members from various regions of India. The programme covered lectures by SPRERI scientists from Bio-conversion technology division (shown below), on various spectroscopic, microscopic, chromatographic, protein purification and molecular biology techniques. An invited talk was also arranged from Bruker Company who delivered a lecture on basic principles of NMR spectroscopy and its industrial applications.

This two-day program helped the participants to gain both theoretical and practical knowledge on instruments such as gas chromatography, high pressure liquid chromatography, NGC-protein purification system, thermal cycler, gel electrophoresis, fourier transform infra-red etc. This program provided insights in instrumentation, application and data interpretation of basic laboratory instruments/techniques, which participants will find useful for both academic and research work.

- Solar energy division had organized a virtual two-day training programme on "Solar Photovoltaic System Design" organized on 1-2 March, 2021. The main objective of the workshop was to train participants on PV system designing. The programme consisted of a well-planned series of lectures explaining the working of each technology and their selection criteria. The sizing of each component using basic governing equations and use of system advisory model software was explained to the participants. The solar energy policy and related government schemes of India were also discussed during this training. A total of 63 participants from colleges

Solar Photovoltaic System Design

and institutes of 12 different states of the country attended this workshop.

- **Extension division** conducted seven online training programmes on various RE technologies, raising awareness of successful approaches related to government policies, finance and technology options and providing information and dispelling myths about RE on zoom platform. 250 students from engineering and science colleges and ITI participated in the training programmes. SPRERI's subject matter scientists and engineers provided training on RE technologies. The lecture series included the basics of different types of RE such as solar, bio-chemical, thermal, bio-gas, bio-fuel and wind energy. The sessions also created an interface for an interactive environment between students and the scientific team of SPRERI.

Webinar on
Renewable Energy Technologies and it's Applications

Date	Title	Speaker
25/08/2020	Bio-renewable Energy for Sustainable Development	Dr. Shaishav Sharma
	Production of Bioenergy and Activated Carbon from Biomass	Dr. Geeta Kumari
	Introduction to Solar Energy Technologies and Sizing of Grid Tied Roof-top Solar System	Dr. Sachin Gupta
	Energy Conservation	Er. Samir Vahora
	Application of Renewable Energy Technologies	Mr. Manoranjan Kumar Shukla
18/09/2020	Solar Energy Technologies and Applications	Er. Asim Joshi
24/09/2020	Bioenergy Status and Potential in India	Dr. Shyamali Sarma
28/09/2020	Waste to Energy Conversion: Gasification of Refuse Derived Fuel	Er. Shardul Amin
03/11/2020	Solar Refrigeration: Introduction, Advancements & Application in Cold Storage Technology	Er. Falgun Raval
04/11/2020	Emerging Role of Bio-Catalysts for Sustainable Bio-fuel Production	Dr. Darshan Rudakiya
05/11/2020	Design, Development, and Performance Evaluation of Improved Biomass Cookstove	Er. Urvish Patel

- A one-day training programme on alcohol based hand sanitizer preparation as per WHO guidelines was organized by SPRERI scientists for women SHGs through District Livelihood Manager (DLM), Gujarat Livelihood Promotion Company (GLPC), Anand team on 3 September 2020 at the bio-ethanol laboratory of the Bio-conversion technology division. 20 women participants from 5 SHGs (Gamadi, Ajupura, Rajupura, Simada and Sarasa villages of Anand district) participated in the training programme (back cover page).

The training programme covered the following modules:

- Awareness tutorial on sanitizer usage as a preventive measure to control spread of COVID
- A detailed protocol of sanitizer composition and preparation was explained by the scientific team of SPRERI as per WHO
- Hands-on training was provided to the SHG members on sanitizer preparation, bottling and labelling
- SHG members were encouraged to follow strict guidelines during the preparation method such as use of gloves, masks and head caps are a must, sanitizer is highly flammable and toxic hence the need to keep a distance from a flame and children
- This program helped the SHG members to build confidence and encouraged them to utilize this training for income generation and self-development
- The training team of SPRERI ensured that all the SHG members gained enough knowledge to start their own sanitizer preparation and distribution program in their respective villages

Open House

SPRERI organized the 13th "Open House" virtually on March 12-13, 2021 (Fig. 33). The purpose was to create awareness of the different RE technologies for students, faculty and the community. Dr. Datta Madamwar, Advisor, PD Patel Institute of Applied Sciences, Charotar University of Science and Technology, Changa inaugurated the programme as Chief Guest and shared his views on utilization of RE technologies in rural, industrial and domestic applications. The program was conducted on zoom platform where around 59 higher secondary school students and teachers and 3182 college students and faculty registered and attended. Scientists and technical staff of SPRERI explained the technologies through online presentations and video and interacted with the participants. On the 2nd day of the Open House, a poster presentation competition was conducted and posters from various institutes were presented on the theme "Innovation in solar thermal technologies for rural application." A Jury evaluated the posters. The top three posters were awarded prizes and certificates. A E-certificate was issued to all the poster presentation participants.

Fig. 33 Group of students attending Open House virtually

Technology Demonstrations

Under **Rural development and DST core support programmes,** demonstrations of various RE technologies for sustainable development were made in the rural areas with the help of SHGs. Details are given below:

Demonstration programme at village level

SPRERI undertook the demonstration of RE technologies *viz.* family size improved biomass cookstove (IBCS), bio-gas plants and micro solar-dome (MSD) with a team from the social work department, Sardar Patel University at Ravipura village, Petlad, Anand and discussed about rural development activities implemented by Sardar Patel University and the Gram Panchyat. The demonstration of family size IBCS, bio-gas plants and MSD were carried out with the help of SHG's and NM Sadguru Water and Development Foundation, Dahod at Vanskhiliya village, Anand and Dahod, respectively. The demonstrations of family size IBCS, bio-gas plants, MSD and sharing information about bio-gas plant was also carried out in 13 villages of Borsad, Anand (Rampura, Bandhani, Pipalav, Kadvapura, Vasna, Vaghvala, Kanbha, Munjkuwa and Gambhira, Haldari Gamadi) and with SARATHI institute, Santrampur, Mahisagar (Page No. 54 & 56).

Based on a survey and demonstrations, a total of 380 nos. of powder coated IBCS were distributed in 6 villages of Chhota-Udepur, Mahisagar and Anand district (Fig. 34). Pre and post installation data of IBCS were collected with the help of kobo toolbox. Based on the observation and collected data, the impact of family size IBCS in rural area of Gujarat were studied (Page No. 54).

Fig. 34 Demonstration of IBCS

SPRERI team have surveyed, demonstrated and distributed MSD to different villages of Anand and Ahmedabad district (Fig. 35). MSD is a day and night lighting device. A total of 34 MSD were installed and pre and post installation data was collected from 20 such installations to evaluate the actual socio-economic benefits. Kobo tool box was used to digitize the data received through the survey form for the impact study. Village wise impact study of the MSD are mentioned below (Table 11).

Table 11: Village wise impact study of MSD

Name of village (District)	Climate of village	No. of installed MSD	Population type	Average day light in winter and summer (h)	Average day light in monsoon (h)	Avg. LED time (h)
Devadthal (Ahmedabad)	Warm semi-arid	4	ST	7.50	6.00	6.00
Isnav (Anand)	Warm semi-arid	6	OBC/Gen.	7.50	5.50	5.00
Haldari (Anand)	Warm semi-arid	9	Gen.	7.67	5.80	6.00
Munjkua (Anand)	Warm semi-arid	1	OBC	7.00	6.00	5.00

According to the Table 11, above the average day light hours in winter and summer season is 7 h and in monsoon 6 h. Maximum LED light illumination during night time is around 5 to 6 h. Based on the collected data, 60% of the population preferred to use the MSD for around 5 h only during the night, whereas, 40% people used it in early morning also for cleaning the house and other household activities. As the maintenance cost for such MSD lighting options is zero, people have preferred to use this over other lighting arrangements and have observed a monthly saving of around Rs. 150 (Page No. 56).

Fig. 35 Demonstration of MSD

A survey to collect the feedback in respect of family size bio-gas plant beneficiaries was conducted. Need based technical guidance regarding maintenance activities was provided to the beneficiaries.

Demonstration of dhabha size IBCS was held at nasta houses, gruh udyog, small restaurants and community based cooking centres of Kheda and Ahmedabad districts (Chaklasi, Pipalaj, Kanjari chowkadi and Devakapura, Kadavapura and Zand (Hanuman), Bodeli, Chhota-Udepur, Anjanva, Santrampur, Mahisagar, SARATHI institute and Devadthal and Navapura, Bavla). During the year, 19 demonstrations were conducted in different villages and 44 nos. of owners had participated. 3 nos. of dhabha size IBCS were set-up near Anand and Chhota-Udepur districts (Fig. 36). Data was collected from dhabha size IBCS to monitor them at the initial stage (Page No. 55).

Fig. 36 (a) Demonstration (b) Implementation (c) Data collection

The base data of all the users has been collected for techno-economic evaluation. It was observed that the nasta center consumes 1 LPG bottle (19.2 kg) and ~150 kg wood per month, the dhabha uses around 40-45 kg wood and small-scale industry consumes around 60-70 kg wood per day. Preliminary feedback collected from users revealed that, dhabha-size IBCS was easy to use for continuous operation. The fuel requirement in force-draft is found to be ~35-40% less compared to the traditional stoves.

Demonstration and evaluation of solar insect trap

Integrated Pest Management (IPM) is an agricultural practice which requires proper monitoring of insect pests and control of those pests at an early stage. The solar insect trap is a device for IPM which uses solar energy. SPRERI procured 10 nos. of solar insect traps developed by Maharana Pratap University of Agriculture and Technology (MPUAT) under the All India Coordinated Research Programme of ICAR. Initially, the performance on battery back-up was evaluated at SPRERI campus. Between December and May month, a total of 8 nos. of solar insect light traps were demonstrated on two farms in Haldari and Isnav villages of Gujarat state (Fig. 37). The traps were monitored daily and the trapped insects collected. The trapped insects were identified with the support of Head of Entomology Department, BA College of Agricultural, AAU. The major insects trapped using the device were of the Hemiptera, Lepidoptera, Hymenoptera, Diptera, Coleoptera and Orthoptera family.

Fig. 37 Solar insect traps installed in farms

Integration of solar dryer with IBCS

In the past, the SPRERI has implemented a few models of stand-alone solar dryers and walk-in type solar dryers. As the solar drying process is restricted to the sunny hours only, to make it continuous, initiated work on integrating solar dryers with the SPRERI designed IBCS through a heat exchanger (Fig. 38).

Fig. 38 (a) and (b) Solar dryer (c) Experimental set-up with heat exchanger

The tests with four different modes were conducted to estimate the performance of the heat exchanger and to estimate the required flow and feed rate to access the drying performance. The results of the different modes are given below for drying of 1.3 kg of tomato (Table 12).

Table 12: Performance of the heat exchanger

Parameters	Types of drying modes			
	Only bio-mass	Only solar	Hybrid (Solar with biomass)	
			With two day drying	With same day drying till late night
Initial moisture (%wb)	93.40	93.70	93.80	93.50
Dried quantity (kg)	0.13	0.13	0.12	0.13
Final moisture (% wb)	9.15	9.46	8.76	10.01
Drying time (h)	~13	22	19.5	16.50
Drying time (including nights) (h)	-	52	29	-
Drying temperature (°C)	54-65	46-55	46-65	46-65
Quantity of wood used (kg)	9.50	0.00	6.41	7.75
Duration of wood used (h)	12.50	0.00	9.00	10:30
Duration on solar radiation (h)	0.00	22.00	10.5	5.00
Cost per kg dried product (without manpower cost)	603	420	637	605

Energy audit of cotton and groundnut farming in Gujarat

An energy audit of cotton and groundnut farming was conducted in the South and North Saurashtra agro-climatic zones of Gujarat. Data was collected from 279 villages of 11 districts. A total of 600 farms of cotton and groundnut farmers were identified to carry out an energy audit as per schedule I and II provided by ICAR. Data were collected on materials, energy used and cost as per Schedule III.

The energy consumed was calculated using conversion factors and the same was expressed in MJ ha^{-1}. The electrical energy in the study area was used mostly by motors to run the irrigation pump set for lifting water. Fertilizer and chemicals were applied in varying quantities depending on the buying capacity of farmers and their preferences. The quantities of different fertilizers and chemicals used on each farm were pooled and the total energy for fertilizer and chemical energy was converted into MJ ha^{-1}. The Specific energy are 0.9-1.8 and 9–28 for cotton and groundnut, respectively.

Networking

Development of peripheral network to rural area and to expand rural development activities, extension division undertook extra activity of supporting rural area of Anand district through distributing face masks during Covid pandemic with the help of Anand District Livelihood team (backside cover page)

SPRERI team also discussed with the DLM Anand district and cluster coordinator of Bodeli, Chhota-Udepur district regarding installation of solar flour mill for joint community development activities in interested remote/tribal/rural area (Fig. 39).

Fig. 39 (a) Meeting with DLM, Anand & (b) Meeting with cluster coordinator of Bodeli, Chhota-udepur

Consultancy Projects

An agreement was signed with the Institute of Rural Management (IRMA), Anand for the implementation of a 150 kg d^{-1} kitchen waste based bio-methanation plant. As per agreement, 150 kg d^{-1} bio-methanation plant was constructed and commissioned at IRMA campus premises, Anand (Fig 40).

Fig. 40 Kitchen waste treatment plant at IRMA

Recognitions & Academic Activities

- SPRERI has been listed as one of the institutes for technology evaluation and validation of DPR for Gujarat for technical appraisal of CBG projects
- Dr. Sachin Gupta, was recognized as PhD supervisor at Faculty of Engineering and Technology, MS University, Vadodara
- Er. Asim Kumar Joshi became a certified trainer conforming to national skill qualification framework level-4: Solar PV Suryamitra (SGJ-Q0101); Solar PV Installer (Electrical) (SGJ-Q0102); and Solar PV Installer (Civil) (SGJ-Q0103) awarded by Skill Council for Green Jobs. Trainer ID - TR164980
- Project title "Catalytic/ non-catalytic oxidative fast pyrolysis of agro-residues and system evaluation" for B.Tech students guided by Dr. Geeta Kumari have been awarded third rank at Project expo 2021 held on 9th June 2021 organized by the Industry Institute Interaction Cell, BVM Engineering College in association with BVM alumni association

Human Resource Development

A three-day workshop on capacity augmentation for the CSG SEED division, DST at IIT Bombay was organized by the Centre for Technology Alternatives for Rural Areas which was attended by the DST core staff from SPRERI. The topics were on the latest advancements in technology like artificial intelligence, machine learning, use of mapping techniques, database management, block chain, self-learning, incubation and start-ups, data collection, analysis and data interpretation, project based learning in embedded systems and robotics, digital fabrication, Q-GIS, SMART village. The open-source software for data collection are now being used in various field-level projects.

Graduate & Post-graduate Dissertations

Student	Mr. Shantanu Pandey & Mr. Anshuman Upadhyay
Programme	Bachelor of Mechanical Engineering
Institute	BVM Engineering College, Sardar Patel University
Division	Solar Energy Division

Student	Mr. Dhwanit Tamboli & Ms. Krishna Chudasama
Programme	Bachelor of Mechanical Engineering
Institute	BVM Engineering College, Sardar Patel University
Division	Thermo-chemical Conversion Technology Division

Student	Mr. Dhurav Kapdi
Programme	Masters in Microbiology
Institute	Shri AN Patel PG Institute of Science and Research, Sardar Patel University
Division	Bio-chemical Conversion Technology Division

Publications

- Sachin Gupta, Sayali Rajale, Falgun Raval, Milan Sojitra, Arunendra Kumar Tiwari, Asim Kumar Joshi and Ramkishore Singh (2020). Comparative performance analysis of flat plate solar collectors with and without aluminium oxide-based nano-fluid. Materials Today Proceeding.
- Asim Kumar Joshi, Sachin Gupta, Arunendra K Tiwari, Falgun Raval and Milan Sojitra (2020). Experimental study of vacuum tube heat pipe-based solar collector for cooking application. (ICSTEED-20).
- Arunendra K Tiwari, Sachin Gupta, Asim Kumar Joshi, Falgun Raval and Milan Sojitra (2020). TRNSYS Simulation of flat plate solar collector based water heating system in Indian Climatic Condition. Materials Today Proceeding.
- Adepu K. Kumar, Shaishav Sharma, Gaurav Dixit, Ekta Shah, Aesha Patel, Grzegorz Boczkaj (2020). Techno-economic evaluation of natural deep eutectic solvent based biorefinery. BIOFPR. 14, 4. 746-763
- Darshan M. Rudakiya and Madhuri Narra (2021). Microbial community dynamics in anaerobic digesters for biogas production. In: Microbial Rejuvenation of Polluted Environment, Microorganisms for Sustainability (Springer).

Conferences, Meetings & Workshops

Conferences

International Conference on Virtual Mode

S. No.	Details of the programme	Date	Scientist/ Research staff
1.	1st International conference on "Innovation in clean energy technology" (ICET-2020), MANIT Bhopal *Oral presentation on* • Comparative performance analysis of flat-plate solar collectors with and without aluminum oxide-based nano-fluid • TRNSYS simulation of flat-plate solar collector based water heating system in indian climatic condition	August 27-28, 2020	Dr. Sachin Gupta Dr. Arunendra K Tiwari
2.	Attended the technical session on "Energy transition: Journey of fossil fuel to RE and bio-energy & reimagining a new India" during the 3rd Reinvest global conference organized by MNRE, New Delhi	November 26-28, 2020	Dr. Madhuri Narra Dr. Geeta Kumari Dr. Shyamali Sarma
3.	5th International conference of International society for environment and sustainability (ISEES) organized by IIT, Guwahati *Delivered a lecture on* • Development of circular bio-economy model for rice straw valorization into bio-energy and by-products with focus on microbial communities" under the technical session held on Biotechnology in sustainable development	December 19-21, 2020	Dr. Madhuri Narra
4.	International conference on smart technologies for energy, environment & sustainable development (ICSTEED-20), GHRCE, Nagpur *Oral presentation on* • Experimental study of vacuum tube heat pipe-based solar collector for cooking application	December 04-05, 2020	Er. Asim Kumar Joshi

Invited/Guest Lectures on Virtual Mode

S. No.	Details of the programme	Date	Scientist/ Research staff
1.	"Current research scenario on solar water pumping system" organized at Mahakal Institute of Technology, Ujjain	July 29, 2020	Dr. Arunendra Kumar Tiwari
2.	"Biomass to bioenergy" organized by St. Joseph's College of Engineering, Deptt. of Chemical Engineering, Chennai under the theme area of "Fostering an effective research environment and industrial collaborations in engineering education"	September 25, 2020	Dr. Geeta Kumari
3.	"Hands-on session on Mesh creation using ICEM" and modelling of solar radiation on fluent during one week online short-term training program on "Fundamentals and applications of CFD" at Sardar Vallabhbhai National Institute of Technology, Surat	September 09-12, 2020	Dr. Arunendra Kumar Tiwari
4.	"Solar refrigeration: introduction, advancements & application in cold storage technology" under webinar series on RE technologies & environmental protection organized by Extension division, SPRERI & at online educational tour organized by State Agricultural Universities	November 03, 2020 & January 27, 2021	Er. Falgun Raval
5.	"Utilization of solar energy technologies: A green way to reduce carbon emissions" during two week national e-training on "Environmental practices and RE utilization" organized under National Agricultural Higher Education Project organized by Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola	January 06, 2021	Er. Asim Kumar Joshi
6.	"Latest trends in solar energy research and application" at Mechanical Department, Narayana Engineering College, Nellore	February 11, 2021	Dr. Arunendra Kumar Tiwari
7.	"Current advancement in solar refrigeration" at Mechanical Department, Visvesvaraya National Institute Of Technology, Nagpur	February 07, 2021	Dr. Arunendra Kumar Tiwari

National Conference

S. No.	Details of the programme	Date	Scientist/ Research staff
1.	Attended the "Scientific interventions in women entrepreneurship:opportunities & challenges" (With special reference to North East)	August 26, 2020	Dr. Madhuri Narra Dr. Geeta Kumari Dr. Shyamali Sarma
2.	Delivered an expert lecture on "Advances in bio-conversion technologies for energy generation and conservation" during one day national webinar on "Role of RE technologies in conservation of energy" conducted by Department of RE Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur on the eve of National Energy Conservation Day	December 14, 2020	Dr. Madhuri Narra
3.	Delivered an expert talk on "Prospects and challenges of bio-energy for sustainable development" organized by SAGE University, Indore on 28 January 2021	January 28, 2021	Dr. Shaishav Sharma

Workshops/Meetings/Trainings/Webinars (Attneded/conducted on virtual mode)

S. No.	Details of the programme	Date	Scientist/ Research staff
1.	"Empretec primer workshop (EPW 46)" by UNCTAD–Empretec programme for India	April 25–May 02, 2020	Dr. Sanjib Karmee Er. Asim Kumar Joshi
2.	3rd steering committee meeting for "Indo-Danish bilateral project" at Aalborg University, Denmark	June 26, 2020	Dr. Gaurav Mishra Er. Asim Kumar Joshi
3.	Webinar on "Women in bio-energy sciences: promoting the bio-economy in the post-COVID era"	June 26, 2020	Dr. Madhuri Narra
4.	"Assessment of phase change materials for thermal management of building" organized by National Productivity Council, New Delhi	July 10, 2020	Er. Milan Sojitra
5.	Current research scenario on "Solar powered water pumping system" organized by Mahakal Institute of Technology, Ujjain	July 29, 2020	Er. Milan Sojitra

S. No.	Details of the programme	Date	Scientist/ Research staff
6.	Webinar on "Transfer of appropriate technologies amongst rural women" organized by Vigyan Prasar, DST, GoI	August 19, 2020	Dr. Madhuri Narra Dr. Shyamali Sarma
7.	Mid-term review meeting of Consortium Research Project on "Energy from agriculture"	August 21, 2020	Scientific and technical staff of BCT & TCC division
8.	One-week online short-term training program on "Fundamentals and applications of CFD" at Sardar Vallabhbhai National Institute of Technology, Surat	September 09-12, 2020	Er. Asim Kumar Joshi Dr. Sachin Gupta Er. Falgun Raval Er. Milan Sojitra
9.	International webinar on "Advance materials in science and technology-2020" organized by Nirma University, Ahmedabad	September 11, 2020	Mrs. Aesha Patel Ms. Nidhi Patel
10.	Academy online FDP on "Green technology & sustainability engineering". A D Patel Institute of Technology, Vithal Udoygnagar	September 21-25, 2020	Er. Asim Kumar Joshi
11.	Presentations made on "SPRERI"s clean energy technologies before the SPOT clean technology review committee, Mission Innovation of India, New Delhi	September 21, 2020	Dr. Gaurav Mishra Dr. Madhuri Narra
12.	One day online training program on "Installation and maintenance of micro solar dome" conducted by NB Institute for Rural Technology, Kolkata	September 26, 2020	Er. Asim Kumar Joshi Er. Samir Vahora Dr. Sachin Gupta Dr. Arunendra Kumar Tiwari Er. Milan Sojitra Er. Falgun Raval Er. Shradhdha Pandya Mr. Paresh Mer
13.	Webinar on ''Showcasing demonstrated waste to value technologies' and presented the technology profile of SPRERI's patented odourless bio-methanation technology during clean technology launch by Dr. Renu Swarup, Secretary, DBT	October 01, 2020	Dr. Gaurav Mishra Dr. Madhuri Narra

S. No.	Details of the programme	Date	Scientist/ Research staff
14.	"Agricultural production and innovation & post harvesting technology" organized by SEED division, DST	October 15-16 & 20-21, 2020	Er. Samir Vahora
15.	Training program on "Fostering instrumental techniques for effective research–2020' organized by Nirma University, Ahmedabad	October 27-31, 2020	Mrs. Aesha Patel Ms. Nidhi Patel
16.	"Allied sector of agricultural" organized by SEED division, DST	October 28-29, 2020	Er. Samir Vahora
17.	Mid-term review meeting of All India Coordinated Research Project on "Energy in agriculture and agro-based indusries	November 02, 2020	All Scientific & technical staff of BCT, SED, TCC & Ext division
18.	One-week short-term training program on "Thermal management: an overview, challenges, and solutions" organized by Department of Mechanical Engineering, Sardar Vallabhbhai National Institute of Technology, Surat	November 02-07, 2020	Er. Asim Kumar Joshi Dr. Sachin Gupta Dr. Arunendra Kumar Tiwari Er. Milan Sojitra Er. Falgun Raval
19.	"Emerging role of bio-catalysts for sustainable bio-fuel production"	November 04, 2020	Dr. Darshan Rudakiya
20.	"MSME and economic sector" organized by SEED division, DST	November 05-06, 2020	Er. Samir vahora
21.	Presented the "progress and completed project reports of DBT sponsored projects" during 4th Task Force Review meeting	November 06&12, 2020	Dr. Madhuri Narra
22.	Online certificate course on "Solar site analysis and energy yield estimation with PVSOL, PVSyst and Sam software application" conducted by National Institute of Wind Energy, GoI	November 18, 2020	Dr. Arunendra Kumar Tiwari
23.	"Social infrastructure sector" organized by SEED division, DST	November 19-20, 2020	Er. Samir vahora
24.	Revised proposal presentation on "STI Hub for Empowerment of Tribal Communities in Gujarat" to the review committee members of SEED division of DST	November 20, 2020	Dr. Gaurav Mishra
25.	"Social infrastructure sector" organized by SEED division, DST	November 26-27, 2020	Er. Samir vahora

S. No.	Details of the programme	Date	Scientist/ Research staff
26.	“Bamboo farming: a successful business (understanding bamboo based livelihood model)” organized by Navjivan Centre for Development	November 29, 2020	Dr. Madhuri Narra
27.	“2D NMR Spectroscopy for structural elucidation of complex small molecules for NMR spectroscopy” organized by SAIF/CRNTS, IIT Bombay	December 02, 2020	Dr. Vaishali Shukla
28.	“Social infrastructure sector” organized by SEED division, DST	December 05-06, 2020	Er. Samir Vahora
29.	”Livelihood and skill development in the post pandemic period” organized by STARS forum during 11th Annual conference	December 08-11, 2020	Dr. Madhuri Narra
30.	4th Steering committee meeting for “Indo-Danish bilateral project” at Aalborg University, Denmark	December 14, 2020	Er. Asim Kumar Joshi
31.	Presented the Annual progress report for GSBTM sponsored project “Next generation bio-lignin nanoparticle synthesis from lignocellulosic agro-residual waste materials using natural deep eutectic solvents”	December 17, 2020	Dr. Shaishav Sharma
32.	Two week NAHEP national e-training on ”Environmental practices and RE utilization” organized by National Agricultural Higher Education Project (IG), Faculty of Agricultural Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola	January 05-14, 2021	Dr. Sachin Gupta Dr. Arunendra Kumar Tiwari Er. Milan Sojitra
33.	Faculty development program on entrepreneurship development in RE sector organized by Centre of Excellence in RE Education and Research Lucknow University, Lucknow	January 20 & February 01, 2021	Er. Asim Kumar Joshi Dr. Sachin Gupta Dr. Arunendra Kumar Tiwari Er. Falgun Raval
34.	Online short-term course on “Spectroscopic techniques for materials characterization” organized by MNIT, Jaipur	January 04-08, 2021	Dr. Vaishali Shukla Dr. Darshan Rudakiya Mr. Priyank Kachhia

S. No.	Details of the programme	Date	Scientist/ Research staff
35.	5th Annual review workshop of Consortium Research Project on "Energy from agriculture" organized by CIAE, Bhopal	January 09-10, 2021	Scientific and technical staff of BCT & TCC division
36.	2-day online training program on "Advance solar PV designing using sketch up" organized by kWatt Solutions Pvt. Ltd., Mumbai	January 29-30, 2021	Er. Asim Kumar Joshi Er. Milan Sojitra Er. Falgun Raval
37.	Training on "Exploring wonders through advance instruments" organized by CHARUSAT University, Changa	February 01-04, 2021	Dr. Shyamali Sarma Dr. Shaishav Sharma Dr. Darshan Rudakiya Dr. Vaishali Shukla Mr. Priyank Kachhia Mrs. Aesha Patel Ms. Nidhi Patel
38.	Completed successfully AICTE training and learning (ATAL) academy online FDP on "Energy storage", Gandhi Institute of Technology and Management, Hyderabad	February 01-05, 2021	Dr. Sachin Gupta Dr. Arunendra Kumar Tiwari
39.	24th Workshop of All India Coordinated Research Project on "Energy in agriculture and agro-based industries" organized by CIAE, Bhopal	February 09-11, 2021	All Scientific & technical staff of BCT, SED, TCC & Ext division
40.	Online training on "PV system designing using helioscope software conducted by kWatt solutions private limited under Skill Council for Green Jobs recognition	February 12-13, 2021	Er. Asim Kumar Joshi
41.	SPRERI's online training program on "Analytical instruments and techniques" for UG, PG, Ph.D and faculty members *Lectures delivered on* • Protein purification techniques • Chromatographic techniques • Spectroscopic techniques • Microscopic techniques • Molecular biology techniques	February 16-17, 2021	Dr. Shyamali Sarma Dr. Shaishav Sharma Dr. Darshan Rudakiya Dr. Vaishali Shukla Mr. Samir Dedania

S. No.	Details of the programme	Date	Scientist/ Research staff
42.	Meeting with Sh. Rajiv Kumar, the project co-coordinator, International Co-operation Department, DST and updated the progress of the ongoing project "On farm demonstration and performance analysis of an off-grid RE driven cold storage"	February 25, 2021	Er. Asim Kumar Joshi
43.	Training on "High-end characterization of microalgae: overcoming the technological barriers" organized by TERI, New Delhi	March 03-04, 2021	Dr. Shayamali Sarma Dr. Shaishav Sharma Ms. Nidhi Patel Mrs. Aesha Patel
44.	Presentation made on new project proposal entitled "Development of a sustainable process for production of value-added products (high purity cellulose and fibers) from agricultural residues for industrial application" to the TEC of GSBTM, Gandhinagar	March 08, 2021	Dr. Madhuri Narra
45.	21st Meeting of "RE sources sectional committee (MED 04)" & 14th meeting of "solar thermal energy sub committee (MED 04:1)"	March 15, 2021	Er. Asim Kumar Joshi
46.	Training of trainers for "Solar PV suryamitra (SGJ-Q0101); Solar PV installer (Electrical) (SGJ-Q0102); Solar PV installer (Civil) (SGJ-Q0103)" organized by Skill Council for Green Jobs	March 22-31, 2021	Er. Asim Kumar Joshi
47.	Training programmes for "Implementation of EAT/REAT module of PFMS" Department of Science and Technology, New Delhi	March 23, 2021	Er. Asim Kumar Joshi Er. Samir Vahora Dr. Geeta Kumari Dr. Shaishav Sharma Dr. Sachin Gupta Mr. Keyur Prajapati Er. Urvish Patel Er. Bhavin Soni Er. Shardul Amin
48.	3rd Annual sustainability fair of "RE & water resources", VFair by IIT, Gandhinagar	March 26, 2021	Er. Samir Vahora

Visitors to the Organization

1. Mr. Purshottam Ramdasi, CEO, Parbhani Agrotech Pvt. Ltd., Aurangabad visited SPRERI on October 13, 2020.

2. Mr. Amit Patel, District Development Manager, NABARD (Handled different NABARD funded projects in Anand and Kheda Districts) and Mr. Kartik Patel, CEO, Anand District Co-Operative Union, Anand (Create and run Farmer Producer Organization (FPO) in Anand district) visited SPRERI on October 28, 2020.

3. Dr. Chetan Singh Solanki, (Prof. IIT Bombay, Member Energy Swaraj Foundation) visited SPRERI on January 20, 2021.

4. Waymade college B.ED students visited SPRERI on February 11, 2021.

5. Dr. Brijesh Patel, Founder & Director, Gdhyana Sanshodhana Nagari Foundation, Vadodara visited SPRERI with volunteers on March 12, 2021.

Team

Director

- Dr. Gaurav Mishra

Solar Energy Division

- Er. Asim Joshi
- Dr. Arunendra Kumar Tiwari
- Er. Milan Sojitra
- Mr. Mukesh Jadav
- Dr. Sachin Gupta
- Er. Falgun Raval
- Mr. Madhendra Padhiyar

Bio-conversion Technology Division

- Dr. Madhuri Narra
- Dr. Shaishav Sharma
- Dr. Vaishali Shukla
- Er. Vinod Kumar Rathod (upto 14.08.2020)
- Mr. Samir Dedania
- Mr. Alok Sivaprasad Vishwakarma
- Ms. Nidhi Patel
- Er. Siddharth Goswami
- Mr. Harman Parmar
- Mr. Ashok Mochi
- Dr. Shyamali Sarma
- Dr. Darshan Rudakiya (upto 22.03.2021)
- Ms. Arjoo Deshpande (upto 14.08.2020)
- Mr. Priyank Kachhia
- Ms. Jinal Upadhyay
- Mrs. Aesha Patel
- Er. Raiyan Vahora
- Mr. Ashok Harijan
- Mrs. Manjula Vadhel

Thermo-Chemical Conversion Technology Division

- Dr. Sanjib Kumar Karmee (upto 09.11.2020)
- Dr. Sreedhar Gundekari (upto 17.12.2020)
- Er. Ganesh Pawar (upto 27.05.2021)
- Er. Bhavin Soni
- Dr. Geeta Kumari
- Er. Shardul Amin
- Er. Urvish Patel
- Mr. Ashok Patel

Technology Transfer & Extension Division

- Mr. Manoranjan Kumar Shukla (upto 15.09.2020)
- Mr. George Michael Samson (upto 31.08.2020)
- Er. Shradhdha Pandya
- Mr. Shailesh Solanki
- Er. Samir Vahora
- Mr. Paresh Mer
- Mr. Minesh Suthar

Administration

- Mr. Keyur Prajapati
- Mr. Hiteshkumar Dalwadi
- Mr. Harshad Suthar
- Mr. Hasmukh Vaghela
- Mr. Dahya Harijan
- Mr. Rajesh Machhi
- Mr. Ishwar Harijan
- Ms. Pragna Dave
- Ms. Krutika Parker (upto 10.11.2020)
- Mrs. Aida Mascarenhas
- Mr. Bhupendra Prajapati
- Mr. Ramesh Bhoi
- Mr. Bhupat Parmar

SARDAR PATEL RENEWABLE ENERGY RESEARCH INSTITUTE - VALLABH VIDYANAGAR

BALANCE SHEET AS ON - 31 - 03 - 2021

FUNDS & LIABILITIES	2020	2021
CAPITAL FUND		
As per last year	**₹ 10,82,669.20**	**₹ 10,82,669.20**
PROJECT FUND		
Balance from last year	₹ 32,22,660.63	₹ 1,92,75,366.58
Add / Less during the year	₹ 1,60,52,705.95	₹ 99,73,879.09
(Annexure - A)	**₹ 1,92,75,366.58**	**₹ 2,92,49,245.67**
EAR MARKED FUND		
1. Building Fund Provision		
Add : During the year		
	₹ 33,64,376.00	**₹ 33,64,376.00**
2. Depreciation Investment Fund	**₹ 4,55,244.00**	**₹ 4,55,244.00**
3. R & D Fund (As per last year)	₹ 81,03,647.83	₹ 81,03,647.83
Add : During the year	₹ 0.00	₹ 0.00
Less : During the year	**₹ 81,03,647.83**	**₹ 81,03,647.83**
DONATION		
Balance from last year	₹ 12,34,001.00	₹ 18,20,101.00
Add : During the year	₹ 5,86,100.00	₹ 0.00
	₹ 18,20,101.00	**₹ 18,20,101.00**
PROJECT EQUIPMENT		
Depreciated value of Equip.from last year	₹ 10,61,44,951.35	₹ 10,79,70,513.60
Add : During the year	₹ 18,25,562.25	₹ 59,61,714.91
Less : Depreciation Annexure - C	**₹ 10,79,70,513.60**	**₹ 11,39,32,228.51**
DEPRECIATION FUND		
As per Block - Annexure - B	**₹ 61,25,628.30**	**₹ 62,92,646.30**
LIABILITIES		
1. Contigent Development Fund	**₹ 1,33,400.00**	**₹ 1,33,400.00**
2. Graduity Fund	**₹ 75,06,526.08**	**₹ 76,95,445.80**
3. Endowment Fund -	₹ 13,13,274.75	₹ 13,59,239.75
Add : During the year	₹ 45,965.00	₹ 40,777.00
Less :	₹ 0.00	₹ 0.00
Annnexure - D	**₹ 13,59,239.75**	**₹ 14,00,016.75**
4. Staff Welfare Fund	**₹ 3,92,334.50**	**₹ 6,95,984.50**
5. Share & Care Fund	**₹ 1,52,835.00**	**₹ 1,52,835.00**
6. Quiz Programme Fund	**₹ 58,262.00**	**₹ 58,262.00**
7. Maintenance Fund (Core Grant)	**₹ 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	₹ 4,89,906.74	-₹ 1,44,609.05
Add - During the year		₹ 1,28,928.20
TOTAL		
Less - During the year	₹ 6,34,515.79	
TOTAL	**-₹ 1,44,609.05**	**-₹ 15,680.85**
TOTAL	**₹ 5,04,10,900.19**	**₹ 6,12,14,072.20**

ASSETS	2020	2021
FIXED ASSETS		
1. Furniture & Fixtures	**₹ 2,49,808.62**	**₹ 2,49,808.62**
2. Electric Fittings	₹ 1,62,350.85	₹ 1,62,350.85
Add : During the year	₹ 0.00	₹ 0.00
	₹ 1,62,350.85	**₹ 1,62,350.85**
3. Mobile Phone	**₹ 19,600.00**	**₹ 19,600.00**
4. Institute Equip.(R & D / Others)	₹ 10,71,372.00	₹ 10,71,372.00
5. Car - GJ-23 AF-0282	₹ 5,85,597.00	₹ 5,85,597.00
6. New Jeep - GJ-23-GA-0488	₹ 8,34,000.00	₹ 8,34,000.00
	₹ 29,22,728.47	**₹ 29,22,728.47**
INVESTMENT		
1. Fixed Deposit	₹ 1,19,46,607.00	₹ 3,55,04,862.68
2. Deposit in LIC - Graduity Scheme	₹ 75,06,526.08	₹ 76,95,445.80
	₹ 1,94,53,133.08	**₹ 4,32,00,308.48**
LOANS & ADVANCES		
1. Tax Deduction at Source	₹ 14,23,275.06	₹ 8,89,673.06
2. Telephone Deposit	₹ 20,313.00	₹ 20,313.00
3. CGM Deposit (Oil Diesel & Petrol)	₹ 12,400.00	₹ 12,400.00
4. Indian Oxyzen Ltd., Deposit	₹ 4,252.94	₹ 4,252.94
5. Mobile Phone Deposit	₹ 4,680.00	₹ 4,680.00
6. Broad Band Security Deposit	₹ 3,000.00	₹ 3,000.00
7. Gas Cylinder Deposit	₹ 10,350.00	₹ 10,350.00
8. Security Deposit (GEB - New DP)	₹ 1,00,920.00	₹ 1,00,920.00
9. Loan to Staff & Advance to Project	₹ 7,29,642.00	₹ 7,29,642.00
10.Intrest Accrued	₹ 4,98,586.96	₹ 5,22,661.01
11. Gujcost to be recover	₹ 0.00	₹ 0.00
	₹ 28,07,419.96	**₹ 22,97,892.01**
BALANCE :		
Bank Balance	₹ 2,51,25,352.68	₹ 1,27,05,975.24
Cash Balance	₹ 1,02,266.00	₹ 87,168.00
	₹ 2,52,27,618.68	**₹ 1,27,93,143.24**
TOTAL	**₹ 5,04,10,900.19**	**₹ 6,12,14,072.20**

Accounts Officer
Sardar Patel Renewable
Energy Research Institute

Accounts Officer

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

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

Chartered Accountants

Director
Sardar Patel Renewable
Energy Research Institute

Director

Date :- 12.07.2021
Place :- Vallabh Vidyanagar

Abbreviations

AAU	-	Anand Agricultural University
AHR	-	Anaerobic Hybrid Reactor
Avg.	-	Average
BIS	-	Bureau of Indian Standards
BS	-	Banana Stem
CaO	-	Calcium Oxide
CBG	-	Compressed Biogas
CD	-	Cattle Dung
CIAE	-	Central Institute of Agricultural Engineering
CNC	-	Cellulose Nano-Crystals
COD	-	Chemical Oxygen Demand
CPC	-	Compound Parabolic Concentrator
CPW	-	Cooked Potato Waste
CS	-	Cotton Stalk
CSG	-	Core Supported Group
d	-	Days
DBT	-	Department of Biotechnology
DLM	-	District Livelihood Manager
DNI	-	Direct Normal Irradiance
DPR	-	Detailed Project Report
DS	-	Dairy Sludge
DST	-	Department of Science and Technology
ETC	-	Evacuated Tube Collector
FBG	-	Fluidized Bed Gasification
Fe_2O_3	-	Ferric Oxide
FID	-	Flam Ionization Detector
FPC	-	Flat Plate Collector
FTIR	-	Fourier Transform Infrared Spectroscopy
GC	-	Gas Chromatography
GLPC	-	Gujarat Livelihood Promotion Company
GNS	-	Groundnut Shell
GoI	-	Government of India
GW	-	Gigawatt
H_2SO_4	-	Sulphuric Acid
H_3PO_4	-	Phosphoric Acid
ha	-	Hectare
HPLC	-	High Pressure Liquid Chromatography
HRT	-	Hydraulic Retention Time
IBCS	-	Improved Biomass Cook Stove
ICAR	-	Indian Council of Agricultural Research
IPCC	-	Intergovernmental Panel on Climate Change
IRMA	-	Institute of Rural Management, Anand
IT	-	Information Technology
KOH	-	Potassium Hydroxide
kW	-	Kilowatt
kWp	-	Kilowatts peak
LED	-	Light Emitting Diode
LMBR	-	Lipid extracted Micro-algae Biomass Residue
Lpd	-	Liter per Day
MCC	-	Micro-Crystalline Cellulose
mg	-	Milligram
min	-	Minutes
MJ	-	Mega Joule
MLD	-	Million Liter per Day
MNRE	-	Ministry of New and Renewable Energy
ms^{-1}	-	Meter per Second
MSD	-	Micro Solar Dome
MSW	-	Municipal Solid Waste
MW	-	Megawatt
NABL	-	Accreditation Board for Testing & Calibration Laboratories
NADES	-	Natural Deep Eutectic Solvents
$NaNO_3$	-	Sodium Nitrate
NaOH	-	Sodium Hydroxide
nm	-	Nanometer
NMR	-	Nuclear Magnetic Resonance
NMS2	-	Nitrate Minerals of Salts-2
O&M	-	Operation and Maintenance
PCM	-	Phase Change Material
PET	-	Poly Ethylene Terephthalate
PLA	-	Poly Lactic Acid
ppm	-	Parts per million
PTS	-	Portable Thermal Storage
PV	-	Photovoltaic
PVA	-	Poly(Vinyl Alcohol)
RE	-	Renewable Energy
RS	-	Rice Straw
RSM	-	Response Surface Methodology
RTC	-	Regional Test Centre
SB	-	Sugarcane Bagasse
SD	-	Sawdust
SEED	-	Science for Equity Empowerment & Development
SEM	-	Scanning Electron Microscope
SHG	-	Self Help Group
SPM	-	Suspended Particulate Matter
SPRERI	-	Sardar Patel Renewable Energy Research Institute
SS	-	Stainless Steel
TEM	-	Transmission Electron Microscope
TGA	-	Thermogravimetric Analysis
TPD	-	Tons per Day
TR	-	Ton of Refrigeration
UTM	-	Universal Testing Machine
v/v	-	Volume per Volume basis
VAbM	-	Vapor Absorption Machine/chiller
VAdM	-	Vapour Adsorption Machine/chiller
VCRS	-	Vapour Compression Refrigeration System
VFA	-	Volatile Fatty Acid
VFD	-	Variable Frequency Drive
VMW	-	Vegetable Market Waste
w/v	-	Weight by Volume
w/w	-	Weight by Weight
WHO	-	World Health Organization
Wm^{-2}	-	Watt per Square metre
WS	-	Wheat Straw
XRD	-	X-Ray Diffraction analysis
XRF	-	X-ray Fluorescence spectroscopy
$ZnCl_2$	-	Zinc Chloride

List of Technologies for Commercialization

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

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
- Gujarat Council of Science and Technology (GUJCOST), Gandhinagar
- Gujarat Energy Development Agency (GEDA), Gandhinagar
- Gujarat State Biotechnology Mission (GSBTM), Gandhinagar

Demonstration of IBCS

Demonstration of dhabha size cookstove

Implementation of biogas plants and MSD

SPRERI's fight against Covid-19

સરદાર પટેલ પુનઃપ્રાપ્ય ઊર્જા અનુસંધાન સંસ્થા દ્વારા સેનિટાઇઝર બનાવવા અંગેની એક દિવસીય તાલીમ યોજાઈ

આને કહેવાય કોરોનાકાળમાં આત્મનિર્ભરતા!

આણંદ તાલુકાના ચાર સ્વસહાય જૂથની મહિલાઓએ સેનિટાઇઝર બનાવવાની તાલીમ મેળવી!