Advanced Bioresidue Energy Technologies Society [ABETS]
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Summary of achievements during the year 2007-08

During the period 2007 – 08, apart from the technological development, the R and D focus was on new areas. This has resulted in proposing to the MNRE projects in the area of Hydrogen generation and Biomass to liquid – frontier areas of research in biomass sector.

Gasification

- Basic studies on Biomass to Hydrogen
- Flame temperature ~ 1500 C achieved with producer gas
- High rate char extraction
- MW level projects operational

Engine

- Producer gas governing achieved for captive power applications
- Dual fuelling at 90 % substitution achieved at MW capacity
- Engine manufactures : Wukeasha and GE Jenbacher, etc are collaborating with IISc for producer gas
- Adapted various gas engines to operate on producer gas

Field experience

- Over 80 % availability of systems for industrial operation
- Over 30 Tons of oil saved daily - 100 tons of CO_2 daily

Other areas

- Power generation using biogas
- Precipitate Silica for industrial purpose
- Over 300,000 domestic stoves from BPEIL

New Areas

- Biomass to hydrogen
- Biomass to liquid
- Waste to energy

Details follow.

Research Highlights

There has been expansion in the field implementation of the technologies developed in the laboratory, in (a) Biomass gasification, (b) Producer gas engines, (c) Activated carbon from the gasifier, (d) Precipitated Silica from rice husk ash and (e) biomass stoves for various applications. Some of the important research contributions are highlighted below.

Gasification

It has been challenging to ensure multifuel capability of the gasification system to handle different biomass and this is **probably the only system design in the world** which uses various agro residues for generating producer gas. This has been possible due to the innovative reactor design and the engineering of the components.

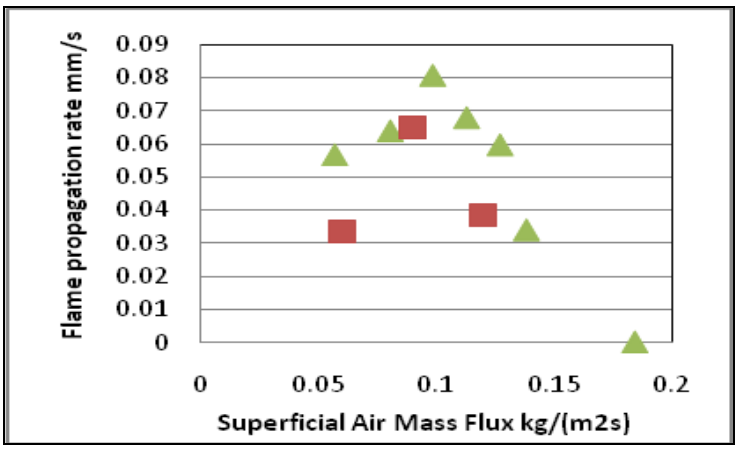
In order to use the same system for other applications, further research in establishing the process parameters had to be investigated. Two such areas will be highlighted.

- **High rate char extraction**
    - Activated char manufacturing industries use char generated from pit method, which is seeing a threat from the pollution control board as emission of obnoxious gases are very high. It has been possible to adapt the gasification system developed at IISc by redesigning few elements and establishing the operating parameters for maximizing energy efficiency and reducing emissions. Towards these basic experiments towards ensuring high char extraction ~ 25 % of the feed material using coconut shells were carried out on an instrumented gasification system. Some important results are
    - Suitable mass flux towards ensuring that the propagation front stabilize the flame zone near the top of the reactor
    - Extraction on a continuous basis with adequate residence time for pyrolysis to be nearly complete

Figure provides the data on the flame propagation front with different air mass flux. It is clear that the peak propagation front is about 0.08 mm/s at a flux of about 0.1 kg/m^{2}s. Beyond this, the propagation rate decreases. This phenomenon is critical while designing the reactor and provides scaling laws for sizing the system. In the case of char extraction systems, it important to have propagation rate on the increasing trend to ensure the flame front is always maintained at the top of the reactor.

The result for a typical gasification system can be handled with a flux range of 0.1 ± 0.03 kg/m^{2}s, which establishes the turn down ratio of the reactor. In the case of char extraction, it is critical and is designed at 0.1 kg/m^{2}s, where the the highest propagation

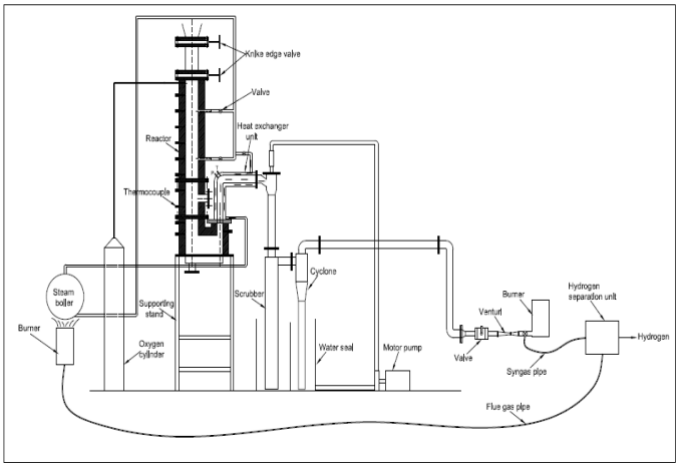
rate is reached. This basic study has provided inputs for designing a 1 ton per hour plant for an industry.



Flame Propagation rate for wood and coconut shells at different flux

- **Hydrogen and liquid fuel generation from Biomass**

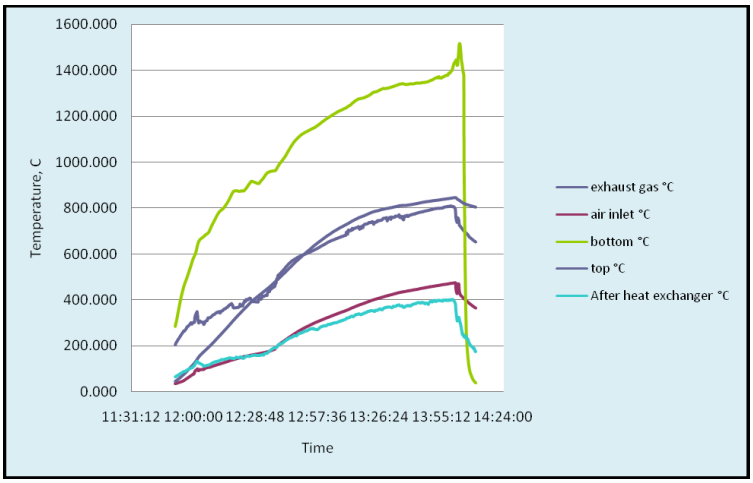
A preliminary investigation into the gasification process for syngas generation which is required for both hydrogen generation and liquid fuel has been carried out. The results indicate that using oxygen for establishing the necessary temperature and steam to enhance the hydrogen concentration in the gas is important. Equilibrium analysis indicate that at steam to biomass ratio of 1:4 along with oxygen, can generate about 130 gms of Hydrogen for every kg of biomass, implying about 25 % of H_2 in from steam used in the reaction. The preliminary experimental results are encouraging.



This part of the research have resulted in proposals for further investigation and technology development

- **Producer gas for High temperature application**

In one of the metallurgical applications regenerator burners are used with lpg as fuel to maintain an ambient of 1000 – 1100°C with various chemical enviornment. The industry has been looking for replacing the expensive fossil fuel by alternate fuel. It was an interesting industrial problem. Other than the fuel and air handling system which was modified to accept producer gas all the other elements were maintained the same in a 40 kW thermal system. Further recuperation was carried out from the exhaust gas. Tests carried on this system revealed that temperature in excess of 1500 C can be obtained using producer gas. This opens up new opportunities in meeting high quality thermal needs using producer gas.



Temperature profile on the insulated burner with recuperator

Engine

Based on research carried out on producer gas engines, IISc has been able draw the attention of a large number of engine manufactures to use their engine on producer gas as a fuel. In India the major engine manufactures like, Cummins India Limited, Greaves, Kirloskar Oil Engines, Kohler have worked with IISc. Of these CIL has taken it forward to provide Producer gas engines for the first time in the power level range of 25 kW to about 240 kW. Large number of engines amounting to about 6 MW for various applications is in use.

One of the important adaptations for the engine operation is the carburetor for producer gas. This has an influence on the load following capability and becomes critical in captive applications. The engines have been used for captive power generation and also grid linking. Special investigations were carried out on the governing capability of the engine under varying operating conditions in an industry. The ISO 8528: part 5 specification was used for the evaluation. These results are very encouraging. Based on the available captive power generation using producer gas with load variation has been addressed only by the

IISc group. G1, G2 and G3 are the class of overall governing to meet various end user applications. see Appendix III for details.

Engines for large capacity have been of serious concern in India as there are no large capacity engine manufacturers here. Based on the gasification system performance in the field, several engine manufacturers are approaching for partnership with IISc to use their engine for producer gas. Further, based on several discussion and meetings with GE, the Jen Bacher group in Austria is very keen in working with IISc. Most of the work carried out by Jen Bacher group has been with grid connected operation in Europe. The group is keen to work with IISc in India.

Technical Highlights

This year has seen significant research input the technology and consolidating the operations in the plant. Further development in the area of dual fuelling, gas engines, silica product, stoves and combustors. Progress made in these fields is described below.

Gasification Technology

On the gasification technology various developments have taken place towards enhancing the contribution of gasification systems in the energy mix. Institutions GE – Jenbacher, Waukesha, Shell, are interested in using IISc design gasification system in several projects.

Further, the industrial plants for captive power generation at MW level have provided an edge over the technology package in the field of gasification. The current industrial experience has proved the technical requirements of an IPP. Plants have been able to operate over 2000 hours of non-stop operation and meet the energy demand of the industry.

One of the major project on using a single 1.2 MWe diesel/HFO engine at high replacements on dual fuel mode with producer gas as the fuel at M/S Sri Gomathy Mills Pvt Ltd., Thirunelvelli dist, Tamilnadu was challenging. This is the first time in India that a single large scale engine is being operated on dual fuel being fuelled with producer gas. The attempt to achieve 90 % savings on the fossil fuel is unique and an essential requirement for economic power generation system using slow speed engines. Such systems are not existing at large power level in this country. This project also has a unique feature of engine manufacturer supporting the engine with dual fuelling with producer gas. The installation had 2 x 850 kg/hr gasification system with the total package including a heat recovery system for fuel drying and also refrigeration load. The refrigeration load is used for process as well as conditioning the textile spinning area.

Critical issue faced during the operation was related to the rate of pressure rise in the engine cylinder in dual fuel operation. This posed a limitation on the engine output and could also could affect the life of the engine with cylinder failure. The engine manufacturer (Anglo Belgium Corporation, Belgium) supported the activity to resolve this issue by reducing the compression ratio and the temperature of the gas inlet.

Performance testing of this engine has been shown very encouraging results. The diesel replacement in the range of 90% at 1.1 MWe was achieved. The industry is now operating the system to meet the energy demand. The fuel consumption has been in the range of 0.75 kg/kWh with additional 30 ml of diesel, amounting to about 28 % efficiency.



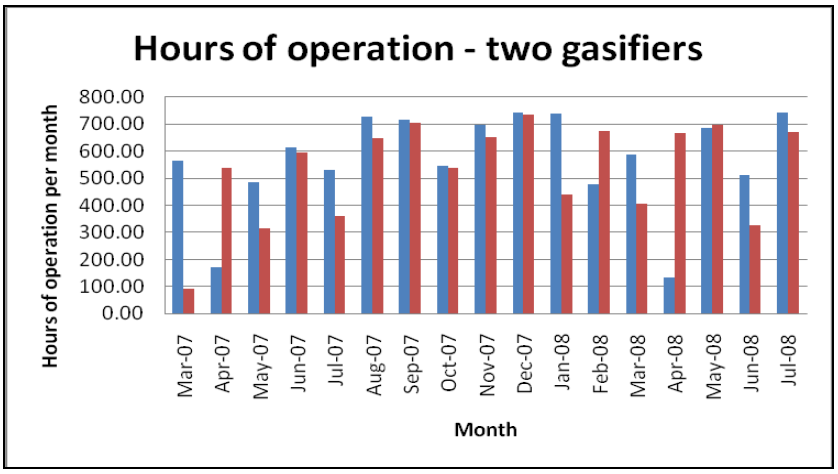

The system package at M/s Gomathi mills, Tirunevelli

MW level Power generation using Gas engine at BMC

The state-of-the-art captive power generation system consisting of 7 X 240 kWe producer gas engines coupled with 2 X 850 kg/hr gasifier was successfully commissioned at M/s Beach Minerals Corporation, Kuttam, Tamilnadu. Individual gasification systems have so far operated around 10000 hours and the total engines hours about 38000 generating about 5.0 million units of electricity. All these engines are in synchronized mode along with the diesel engine etc., which is novel. One of the engines would be generally kept as a standby for any maintenance. CIL is constantly monitoring the performance.

This system was installed in the month of March 2007 and in about 5 months the overall all operational hours was over 2000 hours each on both the gasification system. During this period, both engine manufacturer and the gasifier licensee had to carry out several activities, like linking up the load to the engine, training of manpower, testing of the system under various operating conditions, etc, towards establishing the power plant for long duration operation. During this period both the gasification systems have operated for about 4300 hours generating over 1.4 million units of electricity.

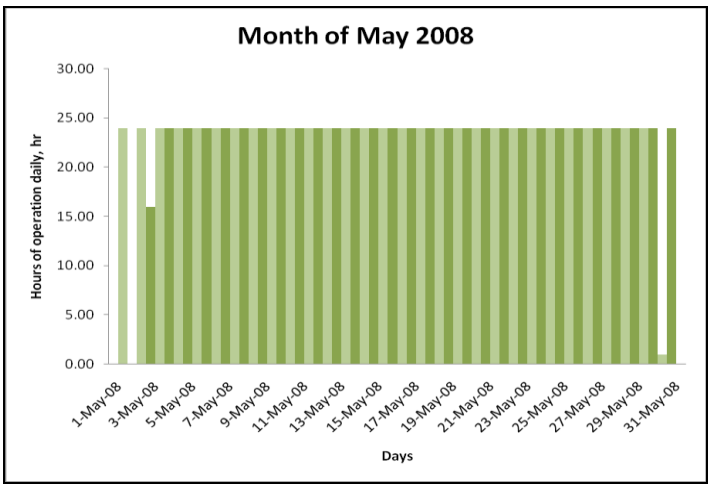
In the last 12 months the system has operated for 14500 hours of operation generating about 4.0 million units of electricity using about 5500 tons of biomass.



Operational hours on both the systems

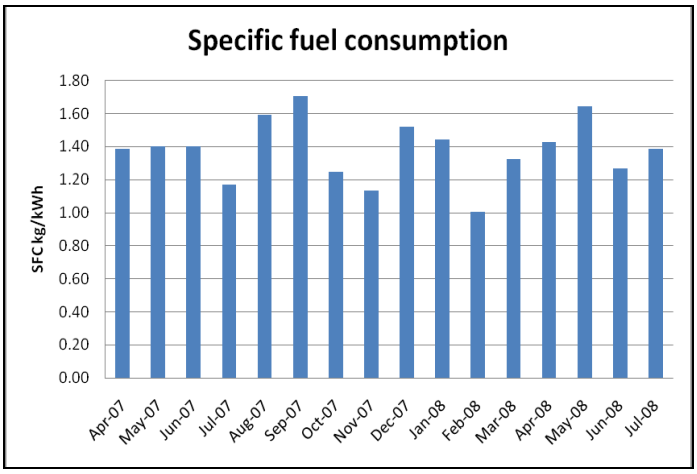
The system has been available for over 82 % of the time. The balance has been due to biomass not available, excessive rains, and some maintenance. This indeed can be taken up to about 90 % with planned maintenance. Figure 1 provides the details of the operational hours over the last 19 months. In the recent time in April 2008, the system was shut down due to an accessory failure.

Figure provides details of power generation for the month May 2008. Both the systems have operated in 24 hour a day and over the entire month. The systems have operated for about 690 hours each during the month. Total generation during the month is about 0.32 million units.



Operational data for the month of May 2008

Specific fuel consumption of biomass has been in the range of 1.1 to 1.64 kg/kWh. Analysing the data, it is evident that at low PLF, average load less than 600 kW, the fuel consumption has been high. In the month of July 2007 the average load was in the range of 780 kW and the SFC is about 1.16 kg/kWh, and also For the month of Feb 2008 the SFC is about 1.0 kg/kWh. In the month of Sept 2007 and May 2008, the average load is the range of 400 kW and hence the SFC is in excess of 1.6 kg/kWh.



Specific Fuel consumption of biomass in different months

The industry has been happy over the financial savings during this period and has been not seriously concered on the obtaining the best performance. The indsutry was depending upon the diesel generation mostly along with the unreliable grid. With a total investment of about Rs. 7.5 crores, the annual savings has been in the range of about Rs. 1.1 Crore. The industry has not availed any subsidy from the government.

Performance of the system in Aluminium Industry

The system which was used in aluminum industry in hot gas mode has been operating efficiently in the industry. The hot gas mode gasifier designed for replacing furnace oil in aluminum utensil manufacturing industry at M/s Kandasamy Metals at Pallakad has operated for over 3600 hours of operation saving about 30 lts of FO hourly. The industry operates for 12 hours daily. The specific energy consumption has been optimized compared to the earlier FO based system by eliminating heat loss. The Oil consumption was 0.25 lts per kg of Aluminum melting and with biomass it is 0.85 kg/kW which is about 3.4 kg/kg of FO. The production output has increased compared to the FO operation due to the optimial design of the furnace and the right A/F for combustion.

Based on the experience in using hot gas, various other applications have been configured

- Two thermal systems of 200 and 400 kg/hr of biomass has been installed to replace about 50 and 100 lts of diesel per hour respectively in Beach Mineral Corporation for sand drying. These were recently installed in April 2008 and have completed about 2000 and 1500 hours of operation. Saving are in the range of Rs. 50 Lakhs over the last 6 months.
- An 1100 kg/hr biomass gasification system to replace about 300 lt/hr of liquid fossil fuel in a boiler for steam generation is being installed at Thai Urethane Plant, situated at the outskirts of Bangkok in Thailand. The novel feature of this power plant is that hot gas is used for the thermal requirement. The system was installed recently and the gas combusted in a commercially sourced dual-fuel burner. The system was tested at partial load to evaluate the performance parameters at component level before taking up the full load operation.

There are also small capacity projects in the range of 25 kW to meet the energy demand of a rural environment and industrial set up.

Gas Engine Technology

Based on the initial work carried out at IISc and further collaborative wok carried out with Cummins India Limited, there are other engine manufacturers interested in working with IISc to use their engine with producer gas as fuel. In this connection M/s Waukesha engine represented by m/s Triveni Engineers in India has offered to support a project in Thailand at 1.5 MW capacity. Based on several technical discussions, 2 nos of 900 kW natural gas slow speed engines will be tried out for power generation in Thailand. The entire fuel handling system including the gas carburetor has be designed by IISc. The system is to be in operation at the end of this year.

Further based on various interaction the group at IISc had with GE, Bangalore and GE Jen bacher in Austria, there has been keen interest by GE to work with IISc on the power generation system packages in India. The engine group is keen in supply engines to IISc licensees and work with IISc on large engine capacity machines. There are several projects planned in this direction.

Precipitated Silica Technology

Most of the research and development activity was carried out to meet various high end uses for precipitate silica from rice husk; a commercial plant was yet to be in place. Recently, a group in India has approached IISc to use the process for generating silica to be used in various sectors. The group is keen and has made necessary market survey for the product. They have found the process to be cost effective and easy to operate. At the end of this year, one ton per day plant will be operational.

Activated Carbon from gasifier operation

Based on the byproduct value of the char extracted from the gasification system at a rate of 5-8 % of the input biomass feed rate with iodine number of more than 500 can be generated from gasifier operation; a few installations adding revenue to the existing stream.

On a specific request from an activated manufacturing industry, which uses coconut shell char generated from pit method as a starting fuel, 1 ton per hour gasification plant has been designed and is being implemented in Tiptur, Karnataka. The process addresses the fuel feeding into the reactor with facility to extract char at 25 % of the input and the hot char can be directly fed into the activation kiln. This ensures nearly zero pollution and also improves the overall energy utilization, yield and quality of activation charcoal. There is a high potential for replication in the activated char sector.

Status of Projects

Strategic Development of Bioenergy - completed

Phase II of the Strategic Development of Bioenergy which comprised of various activities related to research and development, technology package development, training and awareness creation was completed in March 2008. The major areas were

- Development of small power package for village electrification
- Development of large power package for industrial application
- Performance of engine using producer gas
- Producer gas burners for thermal application

The project came to an end in March 2008.

National Focal Point in NBRAP - Progress

The surplus Agro-biomass assessment made using the Atlas developed at IISc clearly indicated that a power generation potential of above 13000 MW in India. As a specific requirement for a project at MNRE under the UNDP-GEF assisted program, a comprehensive estimation of the biomass from all the resources including from Waste lands and Forests was taken up. The selected 8 states are Maharashtra, Haryana, Punjab, Tamil Nadu, Madhya Pradesh, Gujarat, Rajasthan and Uttar Pradesh. Keeping this in view it is proposed in the current context to reassess spatially the biomass resources in the proposed eight states- taluk wise integrating the Areas from Waste land, Forest, Scrub in addition to the Agricultural lands. The necessary district level forest plantation data is taken from the Forest Survey of India (FSI) web site. FSI has conducted ground surveys across the country and has reported district level forest area with species available at state level in a joint effort with NRSA. Based on the a-forestation with observed similarity of plant species being grown in the country shows that the waste land can be treated as an 'extension of forest biomass' in the context of using the surplus woody biomass for power generation. In fact the wasteland can produce more efficiently under planned and managed energy plantations and assist in carbon cycle maintenance. All the data has been transferred to MNRE and the final report on this activity is under preparation.

Gasifiers for urban solid waste

Various agencies were approached to undertake the utilization of urban waste for energy purposes.

- In an attempt to enthuse the state government towards this, KSCST linkages were also used. This has led to move forward in a positive direction with KUIDFC for the Chirtradurga municipality. Several rounds of discussion have taken place and have been indicated that the proposed project for about 200 kW capacity using 15 Tons of organic waste is favorably considered by the decision makers. Various other factors are influencing the progress in this matter – **there has been no progress in the matter.**

- Recently it was proposed to MNRE to set up a demonstration plant at 200 kW capacity, after carrying out necessary R and D. The proposal is to install this package at a site in Bangalore where the municipal wastes is segregated and processed. The proposal has been approved by the R and D committee just receive the sanction letter. There has been some reduction in the budget, which needs to be taken up with MNRE before starting the project. This would help IISc to set up a demonstration plant to convert waste to energy.

Biomass combustion devices

- Further to the technology transfer to BP on the domestic cooking device, they have been able to sell over 300,000 stove in the states of Maharashtra, Tamil Nadu and Karnataka. Based on the current field experience, the version 2 of the system has been developed and necessary actions are being taken towards mass production.
- Basic research on establishing pelletising procedures for various agro residues is being pursued.
- In Kerala, rice flour is process as a product for Puttu making. The industry uses lpg as a fuel. This has been replaced using a novel concept of biomass stove which meets the specifications of the device. The technology is transferred to an industry in Kerala recently.

Hydrogen sulphide scrubbing

A 400 m3/hr scrubbing system is set up as a part of sweetening the biogas for power generation by Anama Energies. The hydrogen sulphide free gas is taken to 2 imported gas engines of 350 kW capacity. The scrubber performance was evaluated at varying operating conditions and has been found satisfactory. The exit H_2S concentration has been in the range of < 10 ppm against the recommended acceptable limit of 100 ppm by the engine manufacturers.

Interaction with International agencies

As a part of an advisory role being by ABETS to the project in Zambia, a 25 kW system to demonstrate the technology package and provide electricity to the ZESCO training centre. The training centre has courses at various levels from 2 weeks to about 1 year in the area of power generation. It had been decided in the National Steering Committee that this would help in ensuring capacity building activity as a part of the national program.

The entire package was build, tested and shipped to Zambia. The faculty from the training centre were trained at IISc for a period of 10 days in operation, maintenance and trouble shooting. The system has arrived in Zambia and there has been delay in the building the shed for housing the gasification system. Based on the recent communication, a team from will reach the site during the 2 week of September for installation, commissioning and on the job training.

Dr. Dasappa visited Zambia to participate in the Steering Committee Meeting in November 2007. It was decided in the meeting that project on 1 MM power station at Kaputa be awarded to IISc. Some exchange of information in this regard has taken place and there has been delay's at various levels.

Dr. Dasappa was invited to present a paper at the the international workshop on "The role of experiments in sustainability transitions in Asia", 10-11 January 2008 held in Chiang Mai University , Thailand organized by the International Human Dimensions Program on Global Environmental Change (IHDP IT), based in Amsterdam.

Dr. Dasappa and Prof. Paul visited Austria and Switzerland to for technical discussion with GE Jenbach for a possible use of gas engines along with collaboration to meet the power requirement in India. The meeting was successful and has resulted in developing few projects at MW level using gas engines. Further, one the plant which had some operational issues in Switzerland was visited and necessary action has been taken to resolve the issue. This has helped in establishing the performance on the GE Jenbach engine, towards strengthening the relationship.

Prof. Paul visited Canada to present the paper at the 29th Symposium (International) on Combustion, August 2008.

Research Activities Planned for the near Future

IISc has been receiving support from MNRE on projects with specific deliverables. In the Month of May 2008, the team from IISc visited MNRE and had a discussion with the then Secretary and Joint Secretary for a possible core support. This suggestion was welcomed and requeted the team to make a presentation to a selected group of officers in MNRE. Based on this MNRE requested the IISc team to prepare a full proposal. The proposal was submitted and reviewed by experts. The same was presented to the R and D committee in the month of June 2008. The proposal was considered favorably in the project mode. The total budget is Rs. 10.35 crores for a period of 4 years with significant support for establish the state of the art laboratory. Executive summary of the proposal is attached in Appendix 1

The following proposal are also cleared with still some issues to be resolved.

- MSW based power project 250 kWe
- Hydrogen Generation from Biomass
- Biomass to liquid through gasification