Strategy on R&D activities for Thermo-chemical conversion and promotion of biomass energy in the country

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Background

As a part of the renewable energy program in India, biomass energy is being considered as an important resource and has been a research focus for a number of institutions within the country. The thermo-chemical conversion process of biomass has been used to meet the energy needs using different technological packages; right from domestic cooking to industrial heat and power. In India, the power potential through surplus biomass is estimated to be 17,000 MWe. So far a total of 901 MWe installed capacity has been set up from biomass as a grid connected power. In addition, around 125 MWe installed capacity has been set up utilizing gasifier systems for off grid /distributed to renewable power (including captive / CHP plants).

The Ministry of New and Renewable Energy (MNRE) is promoting thermo-chemical process based technology package, combustion and gasification power generation systems using locally available biomass resources both in the rural areas and as well as in industrial sectors where surplus biomass such as small wood chips, rice husk, arhar stalks, cotton stalks and other agro residues are available to meet the unmet demands of electricity inter-alia for lighting, water pumping and micro enterprises including telecom power etc. The technology development efforts along with the policy and fiscal / financial incentives introduced by the Ministry have resulted into mega watt installed capacity from biomass power systems.

The current document has received inputs from experts in the field and their contribution to this document is thankfully acknowledged.

Utilization of biomass as a source of energy

There is a considerable potential for biomass energy to replace conventional fossil fuels used for a variety of applications in industrial sector. In applications where the fossil fuel has to be replaced by biomass in the existing device, gasification is viewed as an appropriate technology. For example, there is a good potential for deployment of gasifier systems for the generation of heat in various industries such as bakeries, food processing, silica/ceramics, rice mills, steal re-rolling/scrape, refractory's, cold storages, etc. for meeting the captive energy requirements both heat and power. The gasifiers can also be installed for meeting their captive electricity requirements. However, a different technology packages for replacing fossil fuels in the industrial sector is required where the process requirements are different.

MNRE has recognized the need to take up a task of consolidating the R&D efforts made in biomass energy research and to identify the advanced research activities for pursuance with clear goals for technology development and promotion of biomass energy in the country. Apart from the research, MNRE is focusing on implementation strategy to establish test protocols and standards for biomass energy systems towards meeting both safety and environmental standards. This is being planned through the establishment of test centers in the country.

As a part of this initiative MNRE has supported an R&D project entitled 'Advanced Biomass Research Center (ABRC)' at CGPL, IISc Bangalore in October 2008 to strengthen the expertise of the research group at CGPL for taking up advanced research in biomass energy involving other R&D institutions. As part of the ABRC project, MNRE decided to bring out a clear cut R&D agenda for technology development with strategy on technology packages development, sector wise usage of biomass to replace fossil fuels, etc. for pursuance by research groups in the country. It was decided that the research group at CGPL and MNRE may work together seeking the inputs from the various research groups and consolidate the experience gained in the subject and identifying gaps in technology development and ways for addressing the same along with mechanism for carrying out research identified with expected output and prepare a clear cut R&D agenda for pursuance by research groups.

1. Proposed R&D Strategy and Technology Packages

Major activities of focus are towards the advancement of research on biomass conversion technologies and their end use devices. The work would focus on evolving suitable strategies and management approaches, training and networking among biomass users and academic activities relating these aspects.

- Enhancements to existing biomass resource assessment and management strategies to cover wider biomass resources and period of analysis.
- Advanced research addressing thermo-chemical conversion of biomass — combustion and gasification, with an emphasis on efficiencies and environmental compliance.
- Establishing of standards, best practices and monitoring protocols in the biomass based projects.
- Development of technology packages for replacing fossil fuels in industries.
- Evolving of specifications and standards for biomass energy devices and providing technical support in establishing test centre.
- Engine research with special reference to Producer Gas Applications and adoption of Natural Gas engines for this.
- Exploring extent of potential for replacement of fossil fuel by biomass in sector-wise industrial and commercial usage.

Based on these areas of R&D activities, a considered approach and focus on the objectives and the methodology for achieving the objectives are presented along with an analysis of present gaps identified in these areas that would justify the strategy adopted. This strategy is aimed at providing guidelines for the R&D activities at IISc and in other institutions that would be conducive in establishing sustainable use of biomass to meet the national energy demands.

1.1 Biomass Fuel

Industrial units attempting to use biomass as a part of the energy mix, face difficulty in sourcing the ready to use fuel on a sustainable manner. There are only few professional groups considering this sector as business activity. As a part of promotional activity, it would be important to document success stories in the country and attempt to create the necessary techno-commercial document for use in the biomass sector. Necessary business model need to be addressed for the development of the field of biomass fuel sourcing.

The focus would be on the existing operational mechanism and develop various scenarios for business prospects for sustainable biomass supply chain. This would be through seminars, field visits, scientific exchanges and workshops.

The above independent activity would facilitate in developing methodology and integrate efforts towards establishing national goals for the promotion of biomass energy. This would complement the efforts of the ministry in the biomass sector.

Present Status

- Availability of national biomass atlas generated by IISc for agro residues which is further extended to waste land and forest residues.
- Biomass characterization of many species is reported and is available for estimating its requirement for different usage.
- In this area of activity research and development work is being pursued leading to establishing higher reliability at relatively lower costs. The effort has been a continuous activity with enhancements in the domain knowledge as well as in the quality and reliability of the data presented. The outcome of the work as a national resource map for the agro-residues projecting the growth and estimates of potential quantities for power generation has been integrated as Internet based application hosted at the MNRE site. This application would continue to get updated with data refinements, updates and add-ons such as biomass residues derived from waste lands and forests and for multiple years, from the ongoing projects now.

Identified Gaps in the area

- Biomass as a source of fuel is mostly an unorganized sector though activities in a few pockets of the country have been there in the area of production and supply of agro-residue briquettes.
- Difficulty in economically sourcing the fuel on a sustainable manner for the required quantity.
- No reliable data on estimates of availability (surplus potential) of biomass as a fuel in any area of the country.
- Some of the constraints in the biomass assessment are the conflict on acceptability of surplus estimates, the wide fluctuation in the procurement price and the reliability of the reported figures based on which the feasibility studies are made for a power project based on biomass. While there have been several traced sources of errors that locate to the data collection, the factors based on social and economic practices could shift the ground reality significantly different from the projected figures.
- Biomass based power generation activity being at a nascent stage the supply-demand chain for the biomass is not properly established leading to an uneven pricing and unstable market conditions for the biomass. This needs a more careful study, evolution of different models applicable different conditions both for collection, distribution and utilization.

Work being pursued to address the gaps

Sr. No	Objectives	Methodology being followed	Expected Output
1.	Biomass availability in India.	Remote Sensing Data collection and processing for the biomass atlas.	Biomass atlas giving area wise biomass availability
2.	Identify the vendors who are currently trading biomass – their present trading capacity and turnover.	Identification of biomass traders to be done via web, telephone/industry directories (if available). After this the suppliers would be contacted and requested for information.	Database on biomass availability including trading activity
3.	Interactions with established traders in the country.	Processing of the information provided and identifying of business people for a seminar/workshop.	Database on status of biomass trading.
4.	Make a business model for trading with available data	Analyzing data for establishing a business model for sustainable supply of biomass	Business Model for mainstreaming of biomass collection and distribution.
5.	Exploration of scientific and viable approaches in realizing the bio-mass potential.	Biomass resource modeling based on remote sensing data is being pursued to estimate biomass availability and to work out economics at taluk level (nationwide) for the all states that covers all the residues including agro, forestry and waste land.	Model for achieving biomass power potential at taluka level in the country.
6.	Analysis of gaps between the projected and estimated biomass availability.	The data consistency, accuracy and year-wise variations are generated and the estimated results are compared with projected ones.	Validation of biomass estimation methodology.
7.	Development of tools for complete assessment from satellite data to the end-use-specific electronic maps.	Building of modules for automating the data deployment in to the atlas, consistency checks and for validation of the data.	Software tools for satellite data utilization.
8.	Analysis and bridging of technology and logistic gaps in entrepreneurship for biomass fuel supply.	To consolidate data on the fuel demand in relation to the potential through interactions with industries and to make suggestions in addressing the gaps.	Business model for demand and supply chain

1.2 Biomass Processing

Even though biomass is being used in various sectors, it needs preprocessing at the user end as against the fossil fuels that have established organizational structure to make it available in ready-to-use form. Depending upon the type of biomass and its properties, different approaches for processing is necessary for combustion and gasification applications. Discrete attempts have been made to establish standardized fuel. In light of the fact that agro residues would make a noteworthy contribution for the energy mix, it is important to evolve suitable and effective approaches for converting biomass residues to usable fuel.

A coordinated this work in evolving the strategies and approaches for biomass processing amongst different groups could lead to a comprehensive document in preprocessing of biomass for various energy applications. The standardization of biomass as fuel would be evolved.

This activity would be pursued at different levels that include laboratory work, discussions with various groups involved in the agro processing industries, equipment manufacturers, workshops, etc. A document addressing technical and operational aspects of various preprocessing would be brought out highlighting the possible solutions to convert the residues to usable fuel.

Present Status

- Tailor made biomass processing equipments are in use now for gasification.
- Usage of waste heat from engine exhaust for biomass drying is being adopted.
- As a part of fuel processing which is a critical requirement, usage of wood flakes/chips is being tried out. This ensures the difficulty currently being faced to reduce the fuel sizing process and contributes towards enhancing the capability of using various wood stocks for gasification.
- Bamboo plantation.

Identified gaps in the area

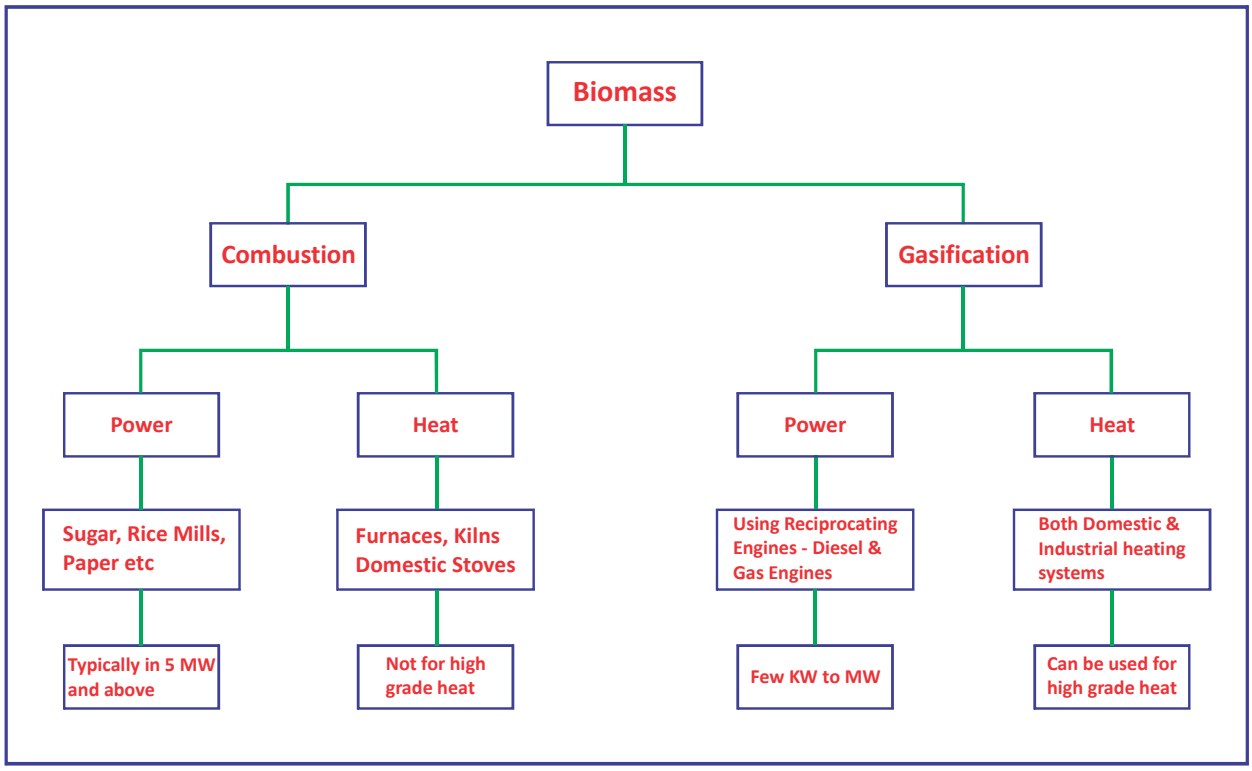
- Non-availability of data on the fuel specifications required for different usages and conversion technologies.
- Non-availability of standardization of processing equipments required to achieve the requirements for specific application.
- No standardization available for agro-residues.
- Poor economics of processing biomass of a particular specification for specific applications.

R & D to address the gaps

Sr. No	Objectives	Methodology being followed	Expected Output
1.	Assessment of the biomass requirement for different energy conversion systems like gasification, combustion and stoves.	Interaction with industries to ascertain their quality and quantity of biomass required for different conversion technologies	Database on current biomass usage in the industries.
2.	Standardization of fuel types for these technologies.	Optimization of characteristics of the biomass required for these technologies in terms of physical and chemical properties.	Recommendations for standardization of biomass fuels for various applications.
3.	Biomass processing required for the fuels.	Survey of biomass processing equipments required to achieve the above and consolidate their effectiveness.	Status on biomass processing techniques.
4.	Present status on biomass processing - mechanisms and scaling.	Organizing scientific exchange programs and workshops with biomass fuel preparation industries and end users to understand the production, utilization and enhancements in the technology to arrive at techno-economically feasible packages.	Enhancements in the technology to arrive at techno-economically feasible packages.
5.	Plan for further activities	Analysis of the whole scenario and providing a road map for biomass processing.	Recommendations for maximizing the availability of processed biomass fuel.

1.3 Biomass conversion technologies

Various biomass conversion technologies currently available are using the solid fuel directly or converting it to gaseous or liquid fuel for different end use application. These conversion technologies are covering domestic and industrial usages, basically in the form of heat to derive power for suitable application.



Present Status

- Different biomass to energy conversion technologies namely – combustion, gasification and bio-methanation are used in the industry extensively.
- Power generation through combustion route is being practiced for capacities in more than 4 MWe level, largely in industries with a co-generation.
- Biomass gasification in capacities of lower than 2 MWe is being pursued substantially across the country both for captive and grid linking applications.
- Pyrolysis of biomass for liquid fuels and charcoal generation.

Identified Gaps in the area

- Non-availability of field-performance data of different biomass technologies.
- Lack of information on suitability of various technologies for specific applications.
- Usage of biomass as a co-firing fuel along with fossil fuel – solid, liquid and gas.
- Pyrolysis studies are not extensive as compared to other conversion technologies.

Work being pursued to address the gaps

Sr. No	Objectives	Methodology being followed	Expected output
1.	Documentation of various biomass conversion technologies its practices globally in order to analyze the performance of technologies.	Literature survey on the existing biomass conversion technologies like gasification, combustion and bio-methanation which would give an insight to their objective, working, salient features and drawbacks.	Database on biomass conversion technologies.
2.	Model development for different applications.	To carry out techno-economic feasibility of the working technologies.	Model for techno-economic evaluation
3.	Biomass stoves • Standardization of the product. • Testing centers for the stoves to be developed. • R & D activities to develop a specific stove for a particular application.	• Present standards would be studied and suitable changes required to meet the specifications to be taken up. • R & D institutions/ Educational institutions/ Test Labs could be trained to be the test centers. • R & D activities to develop tailor made product would be pursued as being done now at the Centre.	• Test protocols for stoves • Identification of test centers
4.	Carbon credits and carbon sequestration.	Analysis of the above for model development for different applications i.e. application of a conversion technology for a specific industry or usage.	Models for carbon credit estimation
5.	R & D work on Pyrolysis to be taken up	Systematic experimental and modeling work on low and high temperature pyrolysis	Process parameters for pyrolysis to generate liquid fuels and chemicals

1.4 Biomass Combustion and Co-firing

Biomass as a fuel for combustion is extensively used. In an attempt to use biomass, many industries adopt ad-hoc solutions to replace the fossil fuel. There are successful attempts in many of these ventures and can be developed further and promoted. Such attempts are not well documented for proper dissemination and their technical and commercial aspects are not well addressed. It is important to understand the technology package, identify the possible short comings, and carry out research at the lab to mitigate this.

The scientific investigation in this connection would address aspects involving fuelling of a system and covers the end use devices for establishing the performance parameters and evolve indicators for the technical, commercial and environmental considerations.

Large scale power plants using biomass as fuel in Independent Power Producer (IPP) and cogeneration sectors are icons for biomass power. A comprehensive attempt to showcase these operations and bring out salient features of these would be part of this activity.

Co-firing is a concept being attempted to replace partially fossil fuel, coal or oil, for economic benefits and carbon credits. In arriving at the technology package for replacing fossil fuel by biomass, critical issues related to the combustion chamber design, heat transfer surface, emissions and operating conditions are vital. These are critically dependent on the type of biomass and its properties. The centre would address these issues at the laboratory to get an insight into these features. Field evaluation of some of the existing systems would be planned for evaluating the performance of the system.

Present Status

- Small and medium scale industries have been using biomass for co-firing.
- Dual fuel application of Producer gas with diesel or furnace oil is being used in many small scale industries.
- The efficiency of the system and the actual amount of fossil fuel has to be looked into where co-firing is carried out.

Identified Gaps in the area

- Lack of study on optimal parameters associated with co-firing of biomass along with fossil fuel.
- Unaddressed operational challenges or changes required for the co-firing.
- Lack of clarity on the required biomass quality for combustion along with fossil fuels.
- Lack of understanding on the extent of co-firing possible with the available resources in the area and process efficiency.

Work being pursued to address the gaps

Sr. No	Objectives	Methodology being followed	Expected output
1.	To generate data on different industrial sectors using fossil fuel to know the type and quantity of fuel used (Solid, liquid/gas) to assess the potential for replacement by biomass.	Survey the different industrial sectors using fossil fuel to know the type and quantity of fuel used (Solid, liquid/gas). Data collection would be done via web, reports from government and private sectors, if necessary field visits.	Data base on fossil fuel usage by industries and potential for fuel replacement by biomass.
2.	Assessment of industries using biomass combustion for meeting their energy needs.	Data collection via web, reports from government and private sectors, if necessary field visits.	Database on the biomass utilization in industries.
3.	Documentation of the success stories and technical difficulties.	Consolidation of the data collected and studies made as above.	Data base on success stories
4.	To assess the impact of biomass co-firing as a replacement in fossil fuel based industries.	Analysis of the existing biomass availability in the region where fossil fuel is to be replaced and arriving at the quantum of biomass needed, techno-economical feasibility and other societal concerns.	Database on possibility of using biomass for co-firing.
5.	To assess the performance of Rural grid towards exploring biomass power deployment for stable power supply	Study the rural grid stability and exploring the possibility of biomass power deployment to supply stable power to grid.	Model for performance evaluation of -rural grid.

1.5 Biomass Gasification

The research and development activities have been focused in establishing technology packages to meet various applications. Apart from the basic research, requirements of the technology packages to ensure safe operations are also addressed.

As a part of the activity of the centre, to carry out the research, augmentation of the laboratory with a fully instrumented gasification system for testing at different end-use applications is taken up. This also supports training programs and technical demonstrations under the scientists exchange program.

Performance evaluation of various industrial burners for producer gas applications are being carried out. Issues related to flame stability, flashback, high temperature application burners etc. are addressed for use with the producer gas that has different properties as compared to the commercial standard fuels.

It is envisaged to take up R & D leading to establishment of specifications standards for the technology package and evolving test procedures towards performance evaluation and ensuring safe and reliable operations. Documentation of the current practices with suggestive guidelines and best practices for industrial usages would be made. Documentation includes the requirements in meeting international standards with environmental conditions and pollution control.

Present Status

- Established technology package for biomass gasification, comprising of various process elements designed to meet the specified performance of the power plant has been achieved with more than 1500 hours of continuous operation and about 6000–7000 hours of operation annually.
- Water treatment plant, critical for the operations as well as meeting the environmental norms has been established.
- Gas clean up system to ensure safe operations of the gasification system established.
- Performance of standard gas burners for usage of hot raw producer gas is being evaluated.

Identified Gaps in the area

- Non-availability of standards for manufacturing of gasification systems.
- Non-availability of test protocols for performance evaluation monitoring.
- Lack of guidelines on safety aspects during construction and operation of gasification systems like monitoring of CO leakage, skin temperatures for safe and comfortable operability etc.,
- Lack of documentation of gasification system performance for different biomass

Work being pursued to address the gaps

Sr. No	Objectives	Methodology being followed	Expected output
1.	Performance evaluation of various industrial burners for producer gas applications	To carry out experiments on different available burners used in the industry for adopting producer gas as fuel	Design of burner for producer gas
2.	Standards for the technology package, testing procedures and protocols towards ensuing safe and reliable field operations gasifier.	Setting up specifications and standards for manufacture of gasification system and components. Evolving of safety measures standards and best practices, to be adopted for the gasification technology. Analysis of existing operating procedures, draw backs and improvisation of the same. Evolving the test protocols for standardization, performance evaluation and safety. R&D institutions to be identified as test centers for gasification.	Standards for manufacturing gasifier and test protocols

1.6 Research on Producer Gas Engines

Currently, natural gas engines are adapted for producer gas application by suitably designing the carburetor and other accessories for smooth operations. Even though a few engines are operational in the industries reliably, there is significant scope for improving the efficiency and output from these engines. Optimization of performance for producer gas is at a very nascent stage and a large amount of research work, involving collaborative effort of engine manufacturers and research institutions, is required for achieving this objective.

The current engines, which are adapted from those designed for natural gas operation, need to be optimized for both output and efficiency. Most of the natural gas engines currently adapted are for stoichiometric conditions and the output is a function of various parameters related to properties producer gas and engine design. These engines are designed for relatively low brake mean effective pressure to address the issues related materials and structural design requirement. Most of the engines are operating at efficiencies and BMEP much below the current international state of the art engines.

Present Status

- Natural gas engines have been adopted for producer gas and have been running successfully in the field.
- Basic carburetion assembly required for producer gas has been achieved.
- Usage of producer gas for optimum engine performance is being addressed.
- Advanced research through measurements and modeling of the combustion processes for producer gas for knocking and turbo charged operations are in progress.
- Large capacity engines in the range of 500 kWe to 2 MWe for producer gas operation being addressed along with engine manufacturers.

Identified Gaps in the area

Natural Gas engines are modified for use with Producer gas. With the change in fuel characteristics there are many areas which need to be addressed for optimization of engines and its accessories.

- Non-availability of commercially standard Carburetor units for Producer Gas application.
- No data on matching of turbo-chargers for producer gas.
- Lack of understanding on the achievable compression ratios of engines for producer gas.
- Limitations in the range of availability of engines for different power levels. For example, non-availability of cost effective producer gas engines at around 10 kWe range required for rural electrification.

Work being pursued to address the gaps

Sr. No	Objectives	Methodology being followed	Expected output
1.	Turbo charger optimization for enhancing the power output of the producer gas engine.	Studying and understanding the characteristics of the available turbo chargers in the market. Matching of suitable turbo charger for the PG engines and optimization of related performance parameters.	Enhancement of power output and efficiency of producer gas engines.
2.	Compression ratio optimization for producer gas engines for enhancing the power output without compromising the engine life.	Some work has been done at CGPL, IISc in understanding the peak power delivered and knocking characteristics. Further work in this direction is being pursued and performance testing on long-duration of the engine with the optimal compression ratio is being carried out.	
3.	Extending the range of producer gas engines of different makes and power levels.	Study on adaptations of different engines and identifying of problems and finding solutions for PG engine suppliers with commercial warranties and guaranties.	Wide range of producer gas engines in terms of capacities and makes
4.	Exploration of adaptation of automobile engines for cost effective small power units for remote applications	Study and testing of refurbished small power automobile engines for application with power levels in the range of 6 to 12 kVA.	Availability of small power producer gas engines.

Suggestions /views on the above R&D strategy document may kindly be sent to this Ministry at the following address:-

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