



CONVERTING WASTE AGRICULTURAL BIOMASS INTO A RESOURCE

Compendium of Technologies

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Compendium of Technologies

Compiled by



United Nations Environmental Programme
Division of Technology, Industry and Economics
International Environmental Technology Centre
Osaka/Shiga, Japan

Preface

Rapid increase in volume and types of waste agricultural biomass, as a result of intensive agriculture in the wake of population growth and improved living standards, is becoming a burgeoning problem as rotten waste agricultural biomass emits methane and leachate, and open burning by the farmers to clear the lands generate CO₂ and other local pollutants. Hence improper management of waste agricultural biomass is contributing towards climate change, water and soil contamination, and local air pollution. Furthermore, this waste is of high value with respect to material and energy recovery.

To manage waste agricultural biomass and to convert it into a material resource, considerable efforts are being made by many Governments and other entities, there are still major gaps to be filled, especially due to its “not in sight and not in mind” phenomenon. There is a lack of awareness and capacity to divert most of the waste for material and energy recovery. This would reduce the costs for waste disposal and would generate the revenue from the sale of the recovered materials and energy.

To raise the awareness and to build the capacity of local stakeholders, UNEP has started to promote **Integrated Solid Waste Management (ISWM) system based on 3R (reduce, reuse and recycle) principle**. This covers all the waste streams and all the stages of waste management chain, viz.: source segregation, collection and transportation, treatment and material/energy recovery and final disposal. It has been shown that with appropriate segregation and recycling system significant quantity of waste can be diverted from landfills and converted into resource.

Developing and implementing ISWM requires comprehensive data on present and anticipated waste situations, supportive policy frameworks, knowledge and capacity to develop plans/systems, proper use of environmentally sound technologies, and appropriate financial instruments to support its implementation.

Many national governments, therefore, have approached UNEP, [as reflected in the decision taken by the UNEP Governing Council/Global Ministerial Environment Forum during its 25th Session in February 2009 (**UNEP/GC.25/CW/L.3**)] to get further support for their national and local efforts in implementation of the Integrated Solid Waste Management (ISWM) programme.

In response to this decision and in line with the Bali Strategic Plan for Capacity Building and Technology Transfer, UNEP has developed a programme on integrated solid waste management. This programme includes support for capacity building and technology transfer for ISWM through a number of actions:

1. Guidelines to develop ISWM System: The four sets of guidelines on ISWM covering waste characterization and quantification, assessment of current waste management system, target

- setting and identification of stakeholders' issues of concern for ISWM, and how to develop ISWM Plan.
2. Pilot projects on ISWM and emerging waste streams including E-waste, waste agricultural biomass, waste plastics and so on
 3. Regional and sub-regional training for policy makers and experts on ISWM and emerging waste streams
 4. Interactive advisory support on ISWM and emerging waste streams

To raise the awareness and to build the local capacity for the designing and implementation of the projects on converting waste into material/resource source, UNEP has started compilation of compendium of technologies for various types of wastes.

This document is compilation of technologies which are in commercial use, under pilot implementation and under laboratory testing for converting waste agricultural biomass into material/energy source. This document is aimed to raise awareness on the available options vis-à-vis technologies as well as to assist the policy –makers and managers in the identification of appropriate technologies with respect to local economic, environmental, social and technical characteristics.

This document can also be of interest to other interested parties/organisations that aim at supporting decision-makers. They may be:

- consultants working on urban services, recycling, or waste management;
- representatives or staff of other local stakeholders including community groups, NGOs, and the private sector;
- entrepreneurs wishing to expand or strengthen their solid waste portfolios;
- academicians and scholars in urban environmental management;
- the press, especially when seeking background materials;
- donors interested in supporting future waste management activities;
- local experts interested in using or replicating the results.

This document and the information available at the website is compiled through best efforts with purpose of creating an information-base with periodic updates based on the feedback from technology experts, providers, suppliers and users. This document is not aimed to advertise or support any specific technology and errors and omissions are not intentional.

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ACRONYMS

CO2	Carbon Dioxide
CV	Calorific Value
DAP	Development Academy of the Philippines
DTIE	Division of Technology, Industry and Economics
ESTs	Environmentally Sound Technologies
E-Waste	Electronic Waste
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning System
IETC	International Environmental Technology Centre
ISWM	Integrated Solid Waste Management
ISWMP	Integrated Solid Waste Management Plan
MBT	Mechanical and Biological Treatment
MC	Moisture Content
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
O&M	Operations and Maintenance
MEAs	Multilateral Environmental Agreements
3R	Reduce, Reuse and Recycle
SAT	Sustainability Assessment of Technologies
UNEP	United Nations Environment Programme
USD	The United States Dollar
WTE	Waste-to-Energy
WWTP	Wastewater Treatment Plant

1. Introduction and Background

Globally, 140 billion metric tons of biomass¹ is generated every year from agriculture. This volume of biomass can be converted to an enormous amount of energy and raw materials. Equivalent to approximately 50 billion tons of oil², agricultural biomass waste converted to energy can substantially displace fossil fuel, reduce emissions of greenhouse gases and provide renewable energy to some 1.6 billion people in developing countries, which still lack access to electricity³. As raw materials, biomass wastes have attractive potentials for large-scale industries and community-level enterprises.

Biomass takes the form of residual stalks, straw, leaves, roots, husk, nut or seed shells, waste wood and animal husbandry waste. Widely available, renewable, and virtually free, waste biomass is an important resource.

With the global campaign to combat climate change, countries are now looking for alternative sources of energy to minimize green house gas (GHG) emissions. Aside from being carbon neutral, the use of biomass for energy reduces dependency on the consumption of fossil fuel; hence, contributing to energy security and climate change mitigation.

Although there is an emerging trend on the utilization of biomass conversion technologies -- from combustion of rice husk and sugarcane bagasse to gasification of other agricultural residues -- biomass is still largely under utilized and left to rot or openly burned in the fields, especially in developing countries that do not have strong regulatory instruments to control such pollutive practices. As a common practice, direct combustion of agricultural residue results in air pollution thereby posing risk to human and ecological health. Biomass is a renewable resource that causes problems when not used. The challenge, therefore, is to convert biomass as a resource for energy and other productive uses.

There are advantages in the use of biomass. Biomass is a renewable resource that has a steady and abundant supply, especially those biomass resources that are by-products of agricultural activity. Its use is carbon neutral, can displace fossil fuels, and helps reduce GHG emissions while closing the carbon cycle loop. As the debate on food versus fuel intensifies, biomass can provide added income to farmers without compromising the production of main food and even non-food crops.

¹ Biomass wastes include agricultural wastes, such as corn stalks, straw, sugarcane leavings, bagasse, nutshells, and manure from cattle, poultry, and hogs; forestry residues, such as wood chips, bark, sawdust, timber slash, and mill scrap; municipal waste, such as waste paper and yard clippings.

² Concept Paper, Using Agricultural Biomass Waste for Energy and Materials: Resource Conservation and GHG Emission Reduction, A Biomass Assessment and Compendium of Technologies Project, UNEP August 2007

³ Annan calls for greater efforts to ensure access by poor to renewable energy, <http://www.un.org/apps/news/story.asp?NewsID=15483&Cr=development&Cr1=> August 19, 2005

2. Rationale

One of the critical activities of the United Nations Environment Program - Division of Technology, Industry and Economics - International Environmental Technology Center (UNEP-DTIE-IETC) is to promote sustainable consumption patterns. It also supports the Bali Strategic Plan for Capacity Building and Technology Support. Given these two thrusts, UNEP-DTIE-IETC conceptualized a project that would promote ecological solid waste management, reduction of greenhouse gases, maximum utilization of resources, and promote energy-efficient and environmentally-sound technologies.

Cognizant of the importance of converting waste biomass into a resource, UNEP-DTIE-IETC partnered with the Development Academy of the Philippines (DAP) in a project that would assess the global production and projection of waste biomass, compile data on existing biomass waste conversion technologies, evaluate these technologies based on the Sustainable Assessment of Technologies (SAT) Framework, develop a framework and conducive policy environment for the promotion of waste biomass use, and identify a site for a pilot demonstration project.

The main objectives of the project are to identify and assess environmentally-sound technologies for converting cellulosic biomass into energy and raw materials, and promote the use of biomass. Its outputs include a global assessment of biomass waste, development of a compendium of waste biomass conversion technologies, assessment of environmentally-sustainable technologies, selection of a project site for a demonstration project, and development of a policy framework for the increased use of waste biomass in a selected region in the Philippines. Overall, the project seeks to raise awareness on cellulosic biomass use globally, especially in developing countries, enable the implementation of such technologies to reduce GHG emissions from the use of fossil fuels, and augment material resources for a variety of products.

One of the major outputs of the project, the Compendium of Waste Biomass Conversion Technologies is an online resource site⁴ of existing conversion systems and equipment utilizing agricultural residues, in commercial, pilot demonstration and research level of use. The Compendium is composed of the following parts:

Part I: Conversion of Waste Biomass to Energy

Part II: Conversion of Waste Biomass to Materials

The primary purpose of the Compendium is to respond to the information needs of decision-makers and end-users in selecting appropriate biomass

⁴ Aside from the Compendium of Biomass Waste Conversion Technologies, the site also features other outputs of the UNEP-DAP Biomass Project such as a global assessment of biomass waste generation and projection, and data on the planned demonstration project.

waste conversion technologies given existing resources and local conditions. It was developed as a resource to provide access to real data and supplement guidance for sound judgment of project implementers.

By making the data on existing conversion technologies available on the internet, utilization of waste biomass is promoted globally. End-users in low income countries are also given equal access to available information. Ultimately, it is hoped that there will be a growing interest in biomass so that it would be seen no longer as waste but as a valuable resource. This interest could be translated into actual utilization of waste biomass especially in areas where it is most needed.

3. Scope and Limitations

In compiling the data for the Compendium, the primary methodology used is data gathering and review of published and online documents on waste biomass conversion technologies. Data from these documents are then organized into fact sheets, which include a summary of technology information, details of the biomass conversion process, and the equipment used⁵.

Technologies listed in the Compendium are limited to those that use cellulosic⁶ agricultural waste biomass. Technologies using exclusively non-waste biomass, such as energy crops like poplars, willows, switchgrass, alfalfa, prairie bluestem, corn, soybean oil and others, are excluded from the Compendium. It also leaves out technologies using animal husbandry waste. However, some technologies included in the Compendium utilize a mix of biomass resources consisting of agricultural residues, energy crops, animal waste and even some inorganic materials such as those found in municipal solid wastes.

Part I compiles technologies that convert agricultural biomass waste into energy products such as heat and steam, electricity, producer gas, synthetic fuel oil, charcoal, methane, ethanol, bio-diesel and methanol. Part II lists down the technologies that convert agricultural biomass waste into raw materials or non-energy products such as cordage, textiles, paper products, upholstery and packaging materials, animal feed, insulators and panel boards, among many others. Each technology datasheet in the Compendium is coupled with a technology assessment sheet⁷ to enable users to decide if the technology is applicable to their needs.

The geographical scope of the compendium is global. Thus, technologies listed range from highly sophisticated equipment from industrialized countries to simple technologies from the developing countries. Different levels of use are also considered, i.e., commercial use, demonstration projects, and research level technologies.

Data gathering was conducted from the September 2007 to May 2008. However, publication date is not a criterion for technology inclusion in the Compendium because the information gathered range from current to as old as five years, as available on the web and other publications. Moreover, a technology or equipment's inclusion in the Compendium does not constitute an endorsement of any kind by UNEP. Rather, it merely provides access to information needed by end users such as farmer groups, non-government organizations, local government units and industry.

⁵ For details, see Part IV: The Compendium

⁶ Cellulosic biomass is composed of cellulose, hemicellulose and lignin, with smaller amounts of proteins, lipids and ash. Examples of cellulosic biomass wastes are rice hull and stalks, coconut coir and shell.

⁷ See annexes for sample of technology datasheet and accompanying assessment sheet

One limitation of the Compendium is insufficiency of data available on existing technologies. This is because online and printed resources do not include all data required in each technology data sheet in the Compendium. Consequently, not all data fields are filled with complete information, which pose a challenge to technology assessment. The online Compendium alone is not enough to meet the growing requirement for current data in the field of waste biomass utilization. To help address this concern, users who wish to get further information on any of the technologies are advised to communicate with suppliers or technology developers whose contact information are provided in the datasheets. They can also visit the website of suppliers which are updated more often. The URLs are provided in the footnotes of the datasheets.

4. The Compendium

The Project Website

The Compendium of Waste Biomass Conversion Technologies is part of the website developed for the Project entitled “Using Agricultural Biomass Waste for Energy and Materials, Resource Conservation and GHG Reduction”. It can be accessed in the URL http://cshd.dap.edu.ph/unep_biomass/. The site shows three major project outputs:

- I. Global Assessment on Cellulosic Waste Biomass
- II. Compendium of Waste Biomass Conversion Technologies
- III. Other Documents

Under the Compendium are two links leading to conversion technologies, first for energy, and second for materials⁸. The point of reference for users is the crop type and the agricultural waste. From here the user can see the different conversion processes and the technologies under these processes. The technology then provides a link to the PDF files of the technology datasheet and technology assessment. It is so arranged so that end users facing solid waste management issues can immediately access information on technologies that utilize the kind of waste that they have or generate. And even before the users click on the link to the datasheet, they can already see what sort of product the conversion process generates.

Completed with the users’ needs in mind, the Compendium features the information materials presented below.

A. Technology Data Sheets

- Crop – agricultural crop that generates the biomass waste
- Residue –waste biomass resulting from harvesting the primary crop, in the technology datasheet, it refers to the main raw material for conversion
- Auxiliary Materials- materials, which may or may not be biomass waste, added to the main raw material for processing
- Process- the biomass conversion procedure, such as combustion, gasification, densification, among others
- Equipment- machine/s used in the conversion process
- Main Products- result of waste biomass conversion, for energy, refers to fuel, heat or electricity, and for materials, whatever product resulting to the conversion process
- By Products- value added products to main product

⁸ Website interface are placed in the annexes.

- Production capacity- refers to the capacity of the equipment to produce a certain amount of energy and non-energy products
- Technical Description of Technology- includes the detailed process description
- Job Potential- the number and nature of jobs that will be generated by technology application
- Parameters for Procurement Specifications- Considerations such as land area required, dimensions of the equipment and other details regarding purchase of equipment
- Operation and Maintenance Requirements- Personnel, technical and other factors necessary for the efficient operation and maintenance of the equipment
- Investment and Operating Cost- Financial considerations in procurement, installation and operation of the system or machinery
- Environmental Considerations- advantages and disadvantages for the environment
- Social Considerations- potential issues and concerns that may arise in the communities where the technology will be applied
- Specific Considerations for developing countries- advantages and/or disadvantages for developing countries
- Institutional and Regulatory Consideration or Requirements- Compliance to international or local regulatory standards
- Process Description- details of the conversion process, whenever available, from collection of raw materials to the conversion process down to the end use
- Price of Machine- cost of the equipment, including transport cost if to be imported
- GHG Emission Reduction Potential- a computation of GHG savings incurred by displacing the use of fossil fuels through use of the biomass conversion technology
- Examples of Real-life Applications- cites location of actual use of technology and level of use, whether commercial, pilot demonstration or research
- Supplier- name and contact information of equipment manufacturer or developer
- Justification/Profitability Indicator- Return of investment and payback period
- Illustrations/graphs/photographs
- Information sources

B. Technology Assessment Sheets

Technology Assessment Sheets accompany each Technology Data Sheet to enable the end users to screen the technologies applicable to local implementation. Assessments include the following information:

- Basic technology information⁹ such as those in the technology data sheets, including crop, residue, process, equipment, main product and by-product;
- Technical component- input and output capacity, equipment/s needed in the conversion process and efficiency of equipment;
- Environmental Component- pollution disposal and control, fossil fuel displacement, compliance to regulatory standards, among others;
- Social Component- potential hazard to community, local acceptability, job generation and other benefits;
- Economic Viability- capital outlay and return of investment, loans and subsidies and incentives, and
- Possible Barriers to Developing Countries- insufficient capability to operate machinery, lack of fiscal incentives to project holders, need for policy measures, among others

Summary of Technology Entries

A. Waste Biomass Resources

For a comprehensive global assessment of waste biomass resources, including waste biomass generation and projection, as well as potential use and equivalent GHG reduction, please see the Report on the Global Assessment of Agricultural Biomass Waste Resources.

The major crops and waste utilized in the Compendium's technology entries are the following:

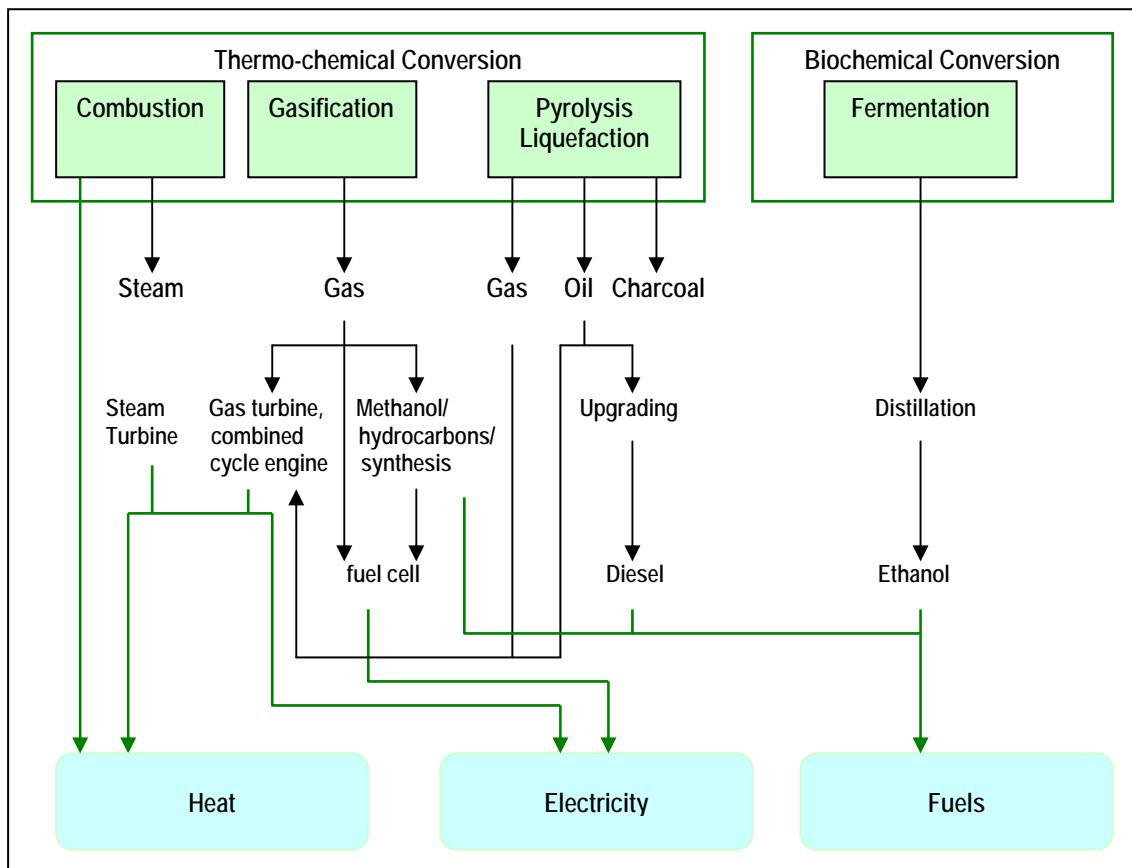
Crop	Waste
▪ Coconut	- Fronds, husk, shell
▪ Coffee	- Hull, husk, ground
▪ Corn	- Cob, stover, stalks, leaves
▪ Cotton	- stalks
▪ Nuts	- Hulls
▪ Peanuts	- Shells
▪ Rice	- Hull/husk, straw, stalks
▪ Sugarcane	- Bagasse
▪ Agricultural Crops	- Mixed agricultural crops, not limited to crop waste
▪ Mixed type	- Agricultural crops and waste including non-organic wastes

⁹ The same information is provided in the assessment to make it user-friendly.

B. Major Waste Biomass Conversion Routes:

Acharya, on the initiatives of ADB on using waste biomass¹⁰, presented major waste biomass conversion routes to energy in a flowchart. Based on Acharya's Biomass Conversion Routes, the following flowchart was designed to include conversion technologies applicable only to agricultural biomass wastes. The flowchart, which does not include routes for energy crops and animal husbandry wastes, summarizes the entries on technology conversion for energy in the Compendium. Mapping out conversion processes down to energy products, the flowchart provides a useful guide to end-users on which technology to consider given their energy product requirement.

Chart I: Conversion Routes for Cellulosic Agricultural Biomass Waste



C. Conversion to energy

Expanding the conversion routes to include the kind of biomass waste and the specific energy product generated, Table 1 is produced to sum up entries for Part I of the Compendium.

¹⁰ ADB's Initiatives on Using Waste Biomass: Agricultural Waste Utilization Project in PRC, presented during the UNEP-DAP International Expert Group Workshop on Compendium of EST for Converting Waste Biomass into a Resource on Nov.13-14, 2007, at the Astoria Plaza, Pasig City, Philippines by Mr. Jiwan Acharya, of the Energy, Transport, and Water Division of the Asian Development Bank

Table 1: Cellulosic Waste Biomass Conversion to Energy

Technology	Conversion Process Type	Biomass Waste	Energy or Fuel Produced
Biodiesel Production	Chemical	rapeseed soy beans waste vegetable oil	biodiesel
Direct Combustion	Thermochemical	agricultural waste mixed waste	heat steam electricity
Ethanol Production	Biochemical (aerobic)	sugar or starch crops wood waste pulp sludge rice and corn straw	ethanol
Gasification	Thermochemical	agricultural waste mixed waste	low or medium-Btu producer gas
Methanol Production	Thermochemical	agricultural waste mixed waste	methanol
Pyrolysis	Thermochemical	agricultural waste municipal solid waste	synthetic fuel oil (biocrude) charcoal

Chart 2: Level of Use for Energy Conversion

		Household energy Briquetting Carbonization Combustion
Bio-chemicals	Bio-oil applications Gasification Pyrolysis	
Research	Pilot Demonstration	Commercial

Chart 2 shows the level of use of the different conversion technologies for energy. Household energy, mainly for cooking, heating and drying, are the most widely available technologies. Biomass cook stoves, for instance, have hundreds of versions all around the world. Those documented in the

Compendium shows existing samples in the Southeast Asia. Gasification and Pyrolysis have most technologies in the demonstration stage. These technologies are concentrated in Europe, USA, Japan and India. Bio-oil and bio-chemical applications are mostly in the research and development stage and are distributed in Europe, North America and Japan.

D. Conversion to materials

Table 2 shows the major conversion technologies for converting biomass waste to materials and their products. It summarizes entries in Part II of the Compendium. The table illustrates the great potential of waste biomass for conversion to a variety of materials.

Table 2: Cellulosic Biomass Waste Conversion to Materials

Conversion Process	Biomass Waste	Product
Bio-reduction	Pineapple leaves Sugarcane residues	Animal feed, industrial absorbents and additives for beverages
	Wheat straw Cotton gin	Wheat straw polypropylene Pelletized feedstock, fertilizer
Bio-refinery system	Rice husk	Silica, Metal Finishing, Water Soluble Oil & Synthetic Lubricant
	Sugarcane bagasse Wheat straw	Lumber materials Panel boards
Decortication	Abaca Leaves	Fiber craft, cordage, textile and fabrics, pulp, and specialty papers,
	Coconut husk	Coconut fiber Rope and twine, brooms and brushes, doormats, rugs, mattresses and upholstery, often in rubberized coir pads
	Pina leaves	Elegant pina cloth
Hot melt process	Kenaf Fibers, Sugarcane bagasse	Paper and packaging materials
Hydro-separation	Sugar mill boiler ash from bagasse	Filtration materials and absorbent products

Molding	Oil Palm fruit residues Sugarcane bagasse	Biodegradable packaging materials Paper and paper wares
Pulping	Kenaf Fibers	Soundproofing systems, thermal insulators
Tuxying	Abaca leaves	Abaca leaf sheath
Twining	Coconut Coir	Coconut twines

Chart 3 shows the level of use for biomass conversion to materials. It shows age-old conversion processes such as twining, decortication and tuxying as the most improved and commercially available technologies. However, it also shows that there is a growing trend in utilizing waste biomass for packaging and even as additive to building materials. Bio-refinery processes and reduction are mostly in research and development stage.

Chart 3: Level of Use for Material Conversion

Bio-refinery Bio-reduction	Molding Hot melt process Hydro-separation	Twining Decortication Tuxying Pulping
Research	Pilot Demonstration	Commercial

5. Conclusion

The Compendium does not claim to be a definitive collection of all existing cellulosic biomass technologies in the world. Although the scope of the Compendium is global, most of the technologies included therein are developed and being used in the USA, Canada, Europe, India and Southeast Asia. It is notable that there is no technology in the Compendium from the Middle East and only a handful come from Africa.

In Africa and other developing regions, dependence on biomass for household needs, such as cooking and drying food or community-level enterprise use, are known to exist but not extensively documented. The Compendium is only limited to data available on the net or in English publications. Another factor is that information on many research and pilot-level demonstration technologies are not yet available on the Internet or in other publications. The challenge now is how to ensure that the Compendium best captures technology available worldwide, especially those existing in developing countries, so that those who need it more can have the ease of access to information on these technologies.

The usability of the Compendium of Biomass Waste Conversion Technologies was tested with the selection of appropriate technologies for a proposed pilot project to be implemented in a selected region the Philippines. Based on the process undergone by the selection of technologies, the Sustainability Assessment of Technologies (SAT), a tool developed by UNEP, the Compendium proves valuable in screening, scoping and selecting technologies appropriate for project implementation¹¹. Through the technology data sheets, the Compendium provided useful data needed to be able to select the appropriate technology for the pilot site.

However, given that some technologies have incomplete data fields, there is a need to intensify and deepen research on the growing number of technologies. Periodic updating and upgrading the Compendium is therefore imperative if it is to be continuously relevant in the future.

¹¹ See Report on Sustainable Assessment of Technologies for UNEP-DAP Biomass Waste Conversion Pilot Project in Nueva Ecija, Philippines.

6. Recommendations

The specific recommendations to improve the Compendium are as follows:

- Convert the existing html-based Compendium in the current website into a database type of content management system to enable ease of access and update of information, or better yet, allow posting of additional data by technology suppliers, users and developers using info-share approach;
- Conduct a wide-ranging public information and communication campaign to popularize the Compendium, especially in developing countries that would best benefit from its use, and
- Include a user-friendly version of SAT in the website so that those who access information on biomass waste conversion technologies will also be able to compare their efficiency and assess their applicability given their local condition and available cellulosic biomass.

Details of Technologies

1. Waste to Energy Conversion

A. Technologies in Commercial Use

2-Drum Top Supported Boiler¹²
USA, Commercial

Crop	Sugar, coconut, coffee, corn, peanut, rice, switchgrass
Residue	Bagasse, coconut hulls, coffee grounds, corn cobs, peanut hulls, rice husks, switchgrass
Process	Combustion
Equipment	2-Drum Top Supported Boiler
Main Products	Heat and Steam

Technical Description of Technology

2-Drum Bottom Supported Boiler Design Parameters	
•Steam capacities	40,000 LB/hr to 200, 000 lb/hr (18 t/hr to 82 t/hr)
•Maximum design pressure	1200 psig (82 bar)
•Maximum steam temperature	900°F(482°C)
•Furnace construction	Tube & tile or membrane wall

M2 Gasification Technology¹³
USA, Commercial

Crop	Sugarcane, forest
Residue	Tar sands, cane stock, forestry, pulp or paper waste
Process	Gasification
Equipment	M2 Gasifier
Main Product	Syngas

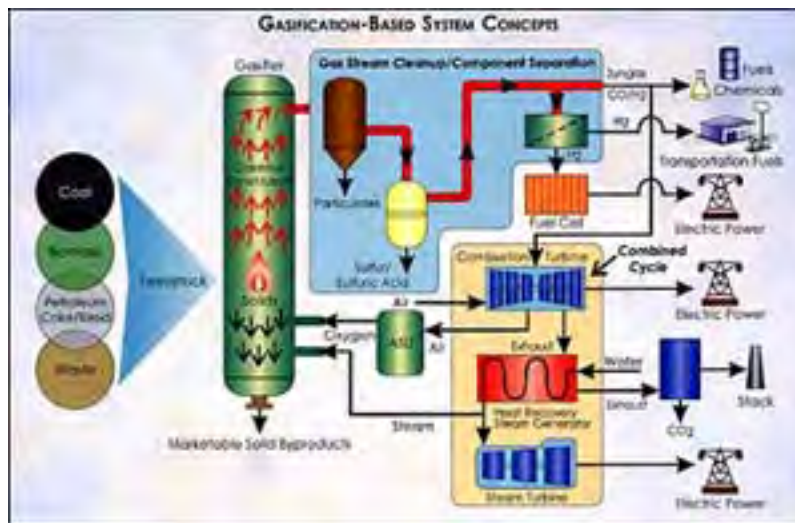
¹² <http://www.mcburney.com/biomass.htm#mod>

¹³ <http://www.syngasinternational.com/technology.html>

Technical Description of Technology

The M2 uses gasification processes to convert any carbon based material into a synthetic gas. Gasification uses heat and pressure which converts any carbon containing materials into synthetic gas composed primarily of carbon monoxide and hydrogen which has a large number of uses. Gasification adds value to low or negative value feedstock's by converting them to marketable fuels. The feed stocks used to create syngas depends on what's readily available. Cheap low grade coal is a readily available supply. In Alberta, Tar Sands provide an abundant fuel source. An application in India under consideration utilizes cane stock from farming waste. Urban applications include garbage and tires. Throughout North America, forestry, pulp and paper waste can be used to be recycled into syngas and fed back into power plants. Various other industrial wastes can be fed back into plants to recycle "lost energy", that would otherwise go to landfills.

According to the US department of energy, gasification may be one of the best ways to produce clean-burning hydrogen for tomorrow's automobiles and power generating fuel cells. Hydrogen and other coal gases can also be used to fuel power generating turbines or as the chemical "building blocks" for a wide range of commercial products.



DOE IGCC Concept

Supplier

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HYBRID PF¹⁴ USA, Commercial

Crop	Agricultural materials
Residue	Agricultural residue
Process	Gasification, combustion
Equipment	Boiler Hybrid PF
Main Product	High pressure steam or hot water

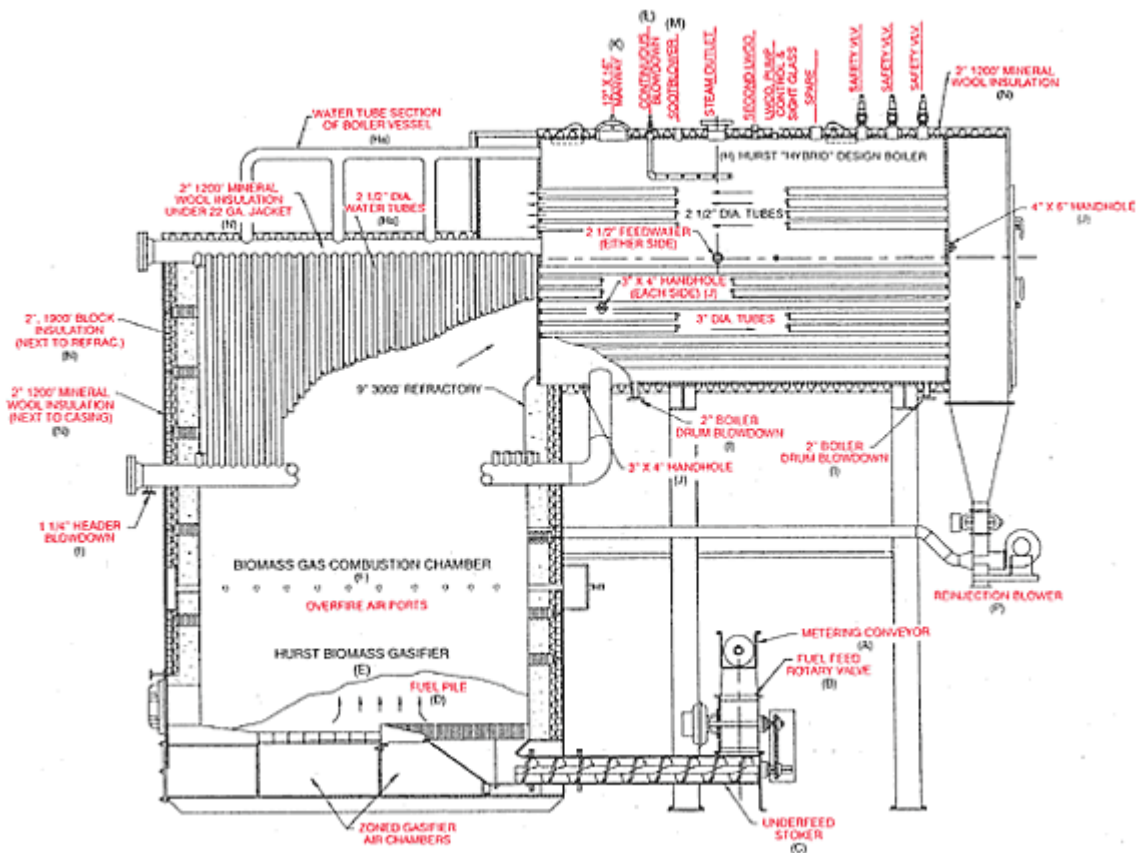
Production Capacity

The Hybrid PF design is suitable for applications to produce high pressure steam or hot water in ranges from 3,450 - 60,000 lbs/hr (3.4 mm BTU - 60 mm BTU) output from 100 up to 400 PSI.



¹⁴ <http://www.hurstboiler.com/biomass.html>

Detailed Process Description



A. Metering Conveyor

Extra Heavy Duty Screw Conveyor with Variable Frequency AC Drive

B. Rotary Air Lock Valve

Limits Excess Air for Improved Combustion Control, Increased Efficiency and Emission Control

C. "Frederick" Solid Fuel Stoker

Manufactured since 1918, it is unsurpassed in the dependable stoking of solid fuels

D. Fuel Pile

The fuel pile, maintained by the stoker, covers all the grates for Improved Combustion Efficiency and Emission Control.

E. Gasifier

A combination of the "Frederick" stoker, combustion air system, and lower combustion chamber. The Hurst "Gasifier" vaporizes the volatile gasses from the solid fuel, driven by the remaining carbon on the grates.

F. Combustion Chamber

Combustion Air is mixed with the volatile gas created by the gasifier and burned in this area of the furnace.

G. Combustion Air System

Two blowers, one under fire and one over fire, furnishes and controls the volume of air entering the Gasifier and Combustion Chamber. All above work in concert to reduce solid fuels into usable heat energy utilizing the most reliable system yet devised. Our "cruise control" system orchestrates the

operation of each to match the steam load and maintain efficient combustion. All above work in concert to reduce solid fuels into usable heat energy utilizing the most reliable system yet devised. Our "cruise control" system orchestrates the operation of each to match the steam load and maintain efficient combustion.

H. "Hybrid" Design Boiler

Originally built in Germany, the "Hybrid" design is unequalled in the heat recovery from solid fuels.

Ha. Water Tube Section

The watertube section of the "Hybrid" boiler allows for abundant radiant heating surface. This allows for quicker recovery and more efficient heat transfer than in the typical firetube boiler.

Hb. Fire Tube Section

The fire tube section of the "Hybrid" boiler allows for greater water volume and thermal reserve than the typical water tube boiler. Quick response with the additional capacity to handle spike loads is the result. In addition, the two pass design increases gas velocity and efficiency and a cleaner boiler result.

Hc. Steam Space

The fire tube section of the "Hybrid" also allows for several times the steam space of a typical boiler. The larger steamrelease surface is calmer, reducing carry over of unevaporated water. The resulting drier steam also reduces system scaling. In addition, dry steam helps eliminate unnecessary extra condensate. Energy and fuel are saved.

I. Boiler Blowdown

J. Handhole

The waterside openings are located in the most effective positions. The lower hand holes offer far better access for both clean out and inspection.

K. Manway

L. Continuous Blowdown

M. Soot Blower

Fixed zone

N. Insulation And Jacketing

2' High Density fiberglass insulation and 22 ga. zinc coated metal jacket.

O. Rear Smoke Box

Liberal and easy accessible gas turn around area. No large refractory doors or wet back to work around.

P. Reinjection Blower

Continuously cleans rear smoke box.

Q. Skids and Support Structure

Unit is skid mounted with rear supports for easy handling and set-up.

Operation and Maintenance Requirements

1. Ash removal is a manual operation.
2. The company stocks replacement parts for the boilers and other major competitors' boilers as well. Manufacturing facility is in Coolidge, GA, supports parts center with the latest technology and competitive rates, offering shipping with Emory, DHL, Fed Ex and "UPS On Line Shipping / Tracking" for speedy delivery of critical parts orders to any facility in a timely fashion.

Examples of Real Life Applications

Commercial use Hybrid PF Highway 319 N. Coolidge, GA 31738

Supplier

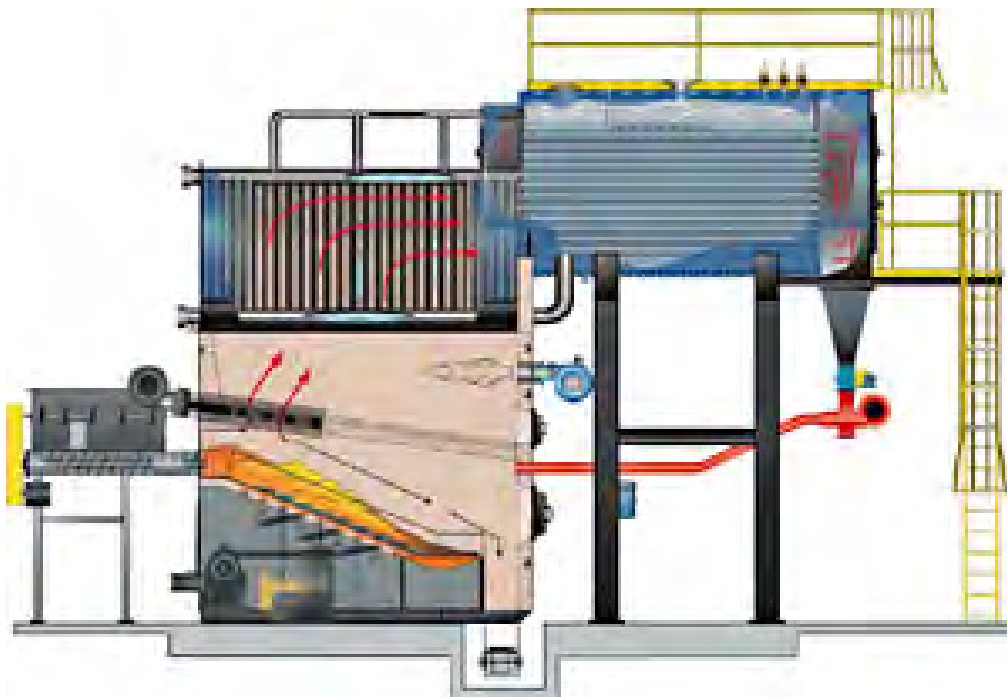
Hurst Boiler and Welding Co., Inc.

HYBRID RG¹⁵ USA, Commercial

Crop	Agricultural materials
Residue	Agricultural residue
Process	Gasification, combustion
Equipment	Boiler Hybrid RG
Main Product	high pressure steam or hot water

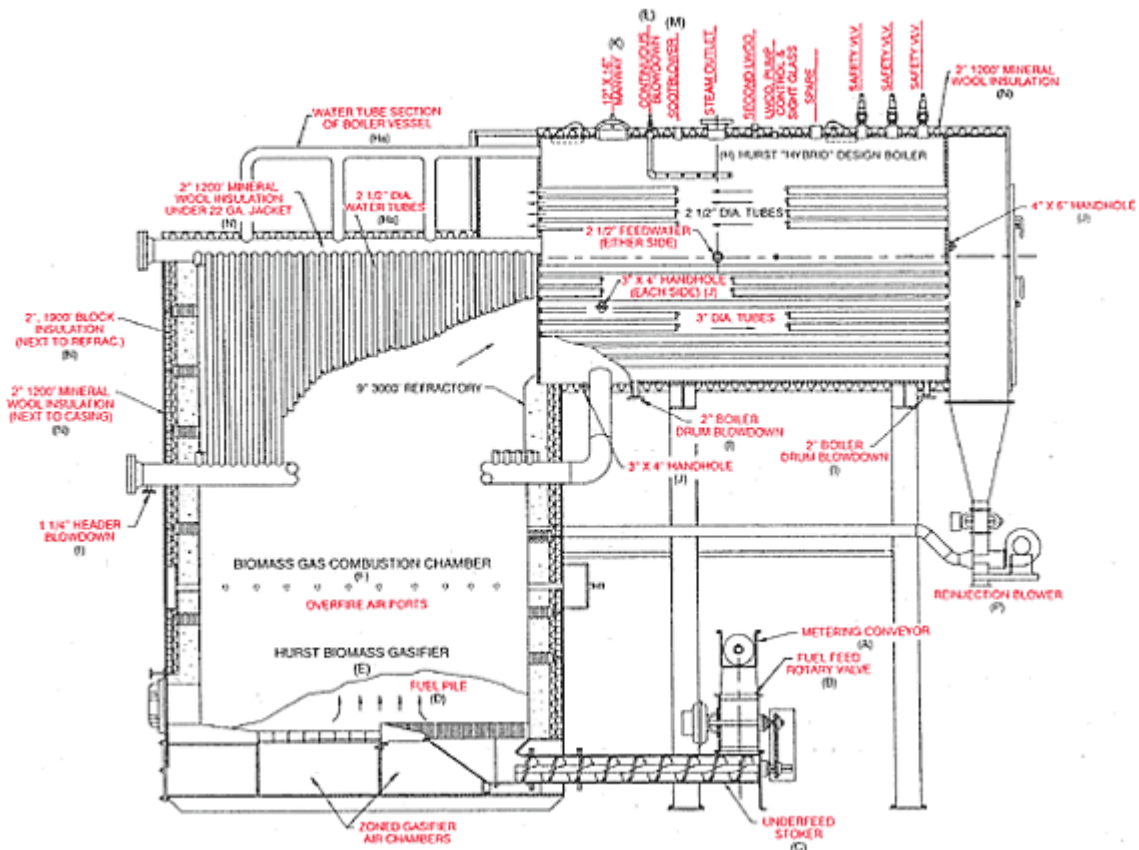
Production Capacity

The Hybrid RG design is suitable for applications to produce high pressure steam or hot water in ranges from 3,450 - 60,000 lbs/hr (3.4 mm BTU - 60 mm BTU) output from 100 up to 400 PSI.



¹⁵ <http://www.hurstboiler.com/biomass.htm>

Detailed Process Description



A. Metering Conveyor

Extra Heavy Duty Screw Conveyor with Variable Frequency AC Drive

B. Rotary Air Lock Valve

Limits Excess Air for Improved Combustion Control, Increased Efficiency and Emission Control

C. "Frederick" Solid Fuel Stoker

Manufactured since 1918, it is unsurpassed in the dependable stoking of solid fuels

D. Fuel Pile

The fuel pile, maintained by the stoker, covers all the grates for Improved Combustion Efficiency and Emission Control.

E. Gasifier

A combination of the "Frederick" stoker, combustion air system, and lower combustion chamber. The Hurst "Gasifier" vaporizes the volatile gasses from the solid fuel, driven by the remaining carbon on the grates.

F. Combustion Chamber

Combustion Air is mixed with the volatile gas created by the gasifier and burned in this area of the furnace.

G. Combustion Air System

Two blowers, one under fire and one over fire, furnishes and controls the volume of air entering the Gasifier and Combustion Chamber. All above work in concert to reduce solid fuels into usable heat energy utilizing the most reliable system yet devised. Our "cruise control" system orchestrates the operation of each to match the steam load and maintain efficient combustion.

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Liberal and easy accessible gas turn around area. No large refractory doors or wet back to work around.

P. Reinjection Blower

Continuously cleans rear smoke box.

Q. Skids and Support Structure

Unit is skid mounted with rear supports for easy handling and set-up.

Operation and Maintenance Requirements

1. The new HBC chain grate-type stoker system permits a wide range of biomass fuels with high ash contents to be combusted in an efficient manner with the added advantage of automatic de-ashing.
2. The company stocks replacement parts for the boilers and other major competitors' boilers as well. Manufacturing facility is in Coolidge, GA, supports parts center with the latest technology and competitive rates, offering shipping with Emory, DHL, Fed Ex and "UPS On Line Shipping

/ Tracking" for speedy delivery of critical parts orders to any facility in a timely fashion.

Example of Real Life Applications

Commercial use Hybrid RG Highway 319 N. Coolidge, GA 31738

Suppliers

Hurst Boiler and Welding Co., Inc.

HYBRID UF¹⁶ USA, Commercial

Crop	Agricultural materials
Residue	Agricultural residue
Process	Gasification, combustion
Equipment	Boiler Hybrid UF
Main Product	High pressure steam or hot water

Technical Description of Technology

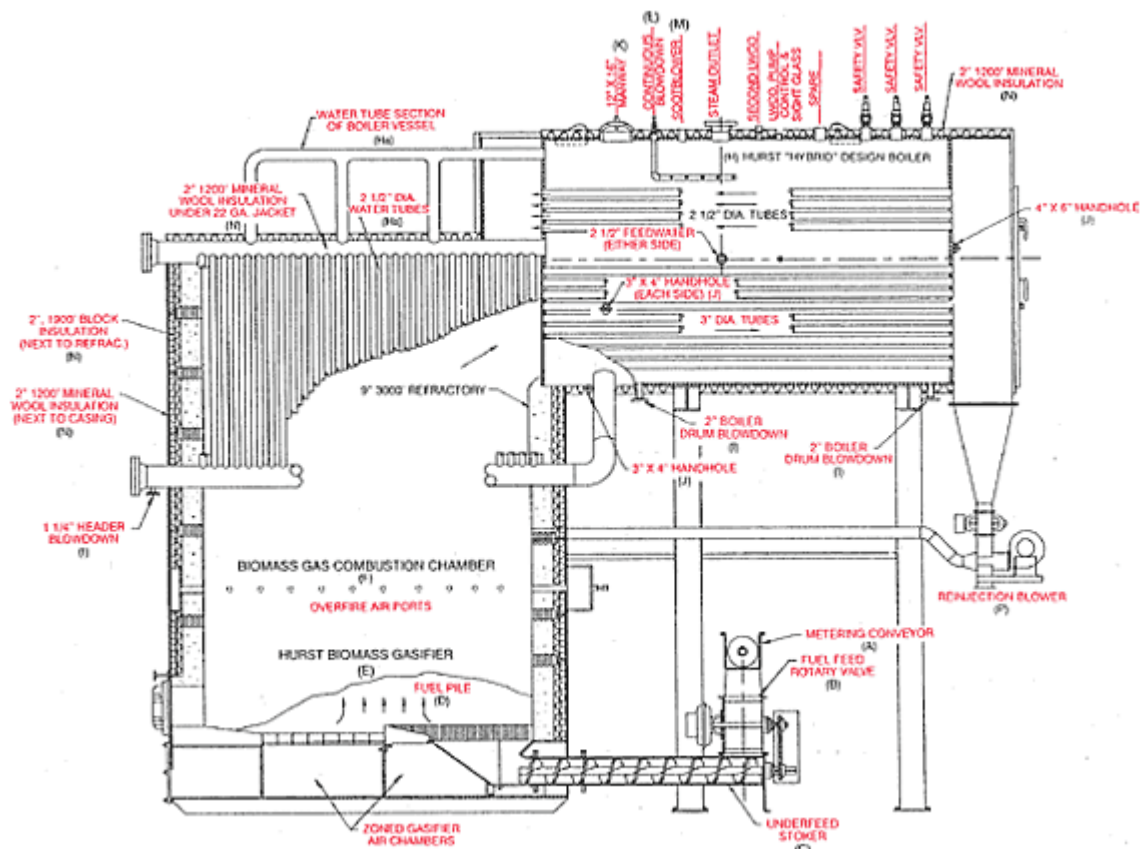


Production Capacity

The Hybrid PF design is suitable for applications to produce high pressure steam or hot water in ranges from 3,450 - 60,000 lbs/hr (3.4 mm BTU - 60 mm BTU) output from 100 up to 400 PSI.

¹⁶ <http://www.hurstboiler.com/biomass.html>

Detailed Process Description



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Extra Heavy Duty Screw Conveyor with Variable Frequency AC Drive

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Limits Excess Air for Improved Combustion Control, Increased Efficiency and Emission Control

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Manufactured since 1918, it is unsurpassed in the dependable stoking of solid fuels

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Example of Real Life Applications

Commercial Use Hybrid UF Highway 319 N. Coolidge, GA 31738

Supplier

Hurst Boiler and Welding Co., Inc.
Highway 319 N. Coolidge, GA 31738

TRI¹⁷
USA, Commercial

Crop	A wide variety renewable organic feedstock
Residue	Agricultural residue
Process	Gasification
Equipment	Gasifier
Main Product	Syngas

Technical Description of Technology

TRI's technology, which processes any organic biomass, including spent liquors, bark, forest residuals, agricultural residuals and energy crops, converts organic carbon to a hydrogen and carbon monoxide synthesis gas ("syngas") that can be used to displace natural gas, be burned in a combined cycle power generation system or be the fundamental building block for the production of biofuels and biochemicals.

TRI's biomass to syngas process can be used to displace or supplement existing chemical and energy recovery systems or integrate a biorefinery into a manufacturing process. The technology offers dramatic competitive advantages to industry in terms of energy efficiency, operating cost effectiveness, environmental compliance, new products, and new revenue streams.

Environmental Considerations

The TRI process is carbon neutral. TRI's biomass-to-energy processes are not water-intensive. Large-scale work with [Norampac](#) in Canada is all done with the client remaining a "zero effluent discharge facility," the highest standard for such a facility.

Examples of Real Life Applications

Norampac Trenton, Ontario, Canada

Norampac is the largest manufacturer of containerboard in Canada. Its Trenton mill produces 500 tons per day of corrugating medium from mixed hardwoods, semi-chem pulp and old corrugated containers (OCC). The mill is a zero effluent facility and is committed to the highest environmental standards and operating efficiency. Prior to installing the TRI spent liquor gasification system the mill had no chemical and energy recovery process. Spent liquor was stored in ponds and sold to local counties for use as a soil binder and dust suppressant on gravel and dirt roads. This practice was terminated in 2002. After reviewing all options for the processing of spent liquor, Norampac chose the TRI system because it would provide the

¹⁷ http://www.tri-inc.net/contact_us.html

capability for both chemical and energy recovery, have minimal environmental impact, have a scale-up and turndown capability to meet current and future mill needs, allow the mill to continue as a zero effluent operation, and be affordable.

The spent liquor gasifier is designed to process 115 Metric tons per day of black liquor solids (at 40% moisture content). The chemicals are recovered and sent to the mill for pulping and the energy is recovered as steam which offsets the production of steam using purchased natural gas. The process started up in September of 2003. The project completed its performance test in April of 2005 and it completed air emissions testing in October 2006 thereby transitioning from commissioning to full commercial operation. The gasifier has logged more than 18,000 hours of operation.

Georgia-Pacific Corporation, Big Island, Virginia

Georgia-Pacific Corporation, one of the world's largest paper companies. The Big Island mill produces 900 tons per day of linerboard from OCC and 600 tons per day of corrugating medium from mixed hardwoods semi-chem pulp. The project was environmentally driven and displaced two 50 year-old smelters that provided chemical recovery but no energy recovery. The project was funded 50% by the U.S. Department of Energy as a demonstration project for low temperature spent liquor gasification. The system was designed to process 200 tons per day of black liquor solids (at 40% moisture).

Starting in the first quarter of 2004, Georgia-Pacific commissioned TRI's steam reforming spent liquor gasification process at its Big Island, Virginia mill. The start-up and operation of the reformer system was not nearly as successful as the similar system at Norampac, and in October of 2006, Georgia-Pacific decided to no longer continue operation of their reformers. Their decision was based on the expected cost of modifying the reformer to improve performance. In contrast to Norampac, GP's system was designed by another engineering company and incorporated significantly different process designs than those implemented by TRI at Norampac.

Suppliers

TRI

3700 Koppers Street, Suite 405 Baltimore, MD 21227

Telephone: 410-525-2400 Fax: 410-525-2408

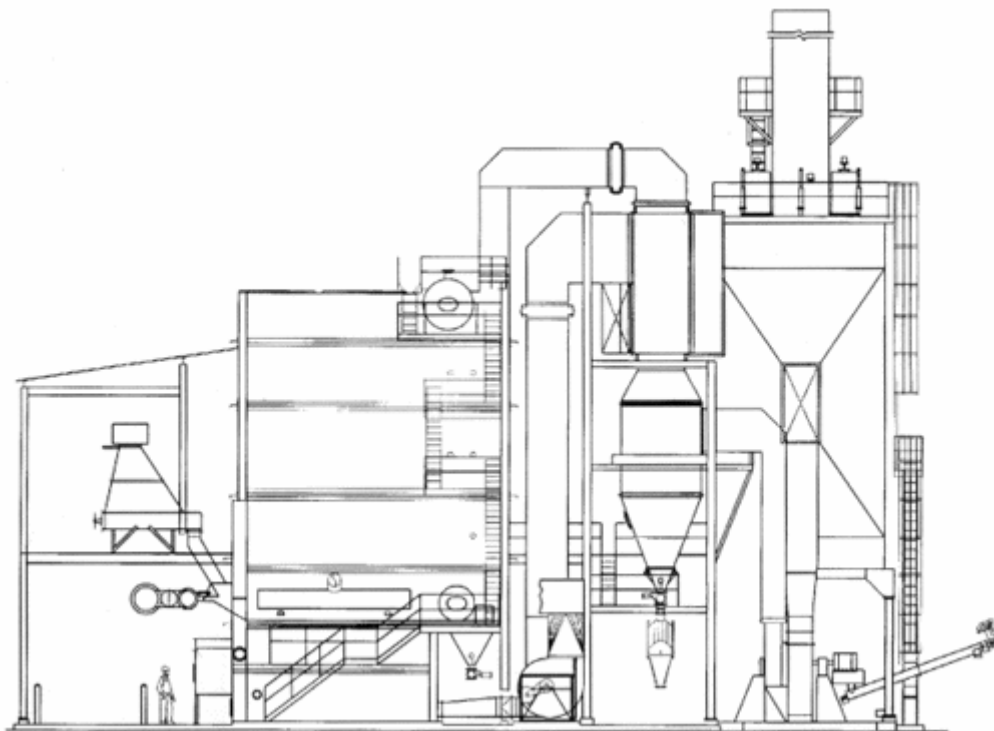
2-Drum Bottom Supported Boiler¹⁸
USA, Commercial

Crop	Sugarcane, coconut, coffee, corn, peanut, rice, switch grass
Residue	Bagasse, coconut hulls, coffee grounds, corn cobs, peanut hulls, rice husks, switch grass
Process	Combustion
Equipment	Boiler
Main Products	Heat and Steam
Production Capacity	

2-Drum Bottom Supported Boiler Design Parameters	
•Steam capacities	40,000 LB/hr to 200, 000 lb/hr (18 t/hr to 82 t/hr)
•Maximum design pressure	1200 psig (82 bar)
•Maximum steam temperature	900°F(482°C)
•Furnace construction	Tube & tile or membrane wall

¹⁸ <http://www.mcburney.com/biomass.htm#mod>

Detailed Process Description



Environmental Considerations

Company has air pollution control system

Institutional and Regulatory Consideration or Requirements

- Performed in strict accordance with the applicable ASME Boiler and Pressure Vessel Codes, the National Board Inspection Code, and any jurisdictional requirements that may apply. McBurney currently holds the following ASME and National Board Certificates of Authorization:

- A** for the assembly of power boilers which are designed and manufactured by others.
- PP** for the design, alteration, manufacture, and erection of power piping.
- R** for in-kind repair of boilers and pressure vessels.
- S** for the design, alteration, manufacture, and erection of

power boilers.

Examples of Real Life Applications

Commercial use 2-Drum Bottom Supported Boiler 1650
International Court

Suite 100 Norcross, GA

30093

Supplier

McBurney

**100 kWe Talbott's Biomass Generator
United Kingdom, Commercial**

Crop	Energy and Agricultural crops
Residue	Forestry and agricultural wastes, woodchips, wood pellets and energy crops and Miscanthus
Process	Combustion
Equipment	Bunker, combustor, biomass turbine generator
Main Product	Combined heat and electricity

By-Product

Technical Description of Technology

The Biomass Generator (BG100) is a highly efficient technology capable of producing 100kW of renewable electricity and 200kW of renewable heat. Fuels that can be used in this unit include wood chips, forestry and agricultural residues, short rotation coppice, such as willow, and energy crops, such as Miscanthus. The BG100 converts this biomass, through combustion, into energy in the form of electricity and heat.

The size makes the BG100 ideal for installation on farms, large estates, woodworking factories and anywhere where there is a readily available source of fuel. This technology will lead to added value for crops and will offer an effective end use for energy crops. It will also provide an opportunity to the agricultural community for a much needed, viable diversification option.

The BG100 is a small, compact system designed for on-site power production. Transport of fuel is minimised through the utilisation of on-site or local fuel sources, achieving further emission reductions directly related to the use of this system.

Plant Specifications	
Electrical Power Output (rated)	80 to 100 kW
Generating Voltage/Frequency	415V/ 3 phase / 50 Hz
Grid Protection	Software G59 compliant
Fuel Type	Biomass
Thermal Output	200 to 250 kW
Heat Output Format	Hot water up to 90 degrees Celsius
Operation	Fully Automated Continuous Output

Detailed Process Description

A fully automated continuous system ensures proper fuel feeding to maintain the required energy output and the step-grate system helps to ensure even burn throughout the combustion chamber to improve the unit's efficiency.

A triple pass ceramic lined high temperature combustion zone helps maximise efficiency and high combustion temperature making it possible to use fuels with a higher moisture content than would otherwise have been possible. High combustion temperatures ensure clean combustion, meeting all environmental standards. Step grate system with auto de-asher ensures even burn throughout combustion chamber for improved efficiency.

Bunker fuel storage systems are used for ease of loading by a variety of methods with additional storage capacity. Robust, variable fuel mechanism allows varying sized specified biomass to be fed into the boiler.

The indirect fired micro turbine is an integral part of the BG100. High-speed direct drive engine coupled to power electronics to provide high levels of engine efficiency and remove the need for a reduction gearbox and the losses associated with it.

Main Products

Combined heat and electricity

Environmental Considerations

The 100kW of renewable electricity and the 200kW of renewable heat produced by the system will lead to a carbon dioxide emission reduction of around 600 tonnes per unit each year; this is compared to emissions from fossil fuel fired heat and electricity production. This is a significant saving which will greatly benefit the environment by reducing the release of carbon dioxide, a greenhouse gas, into the atmosphere.

Investment and Operating Cost

Processed biomass fuel is ready to be fed into a biomass energy system The BG100 can be operational for approximately 8000 hours per annum.

Examples of Real Life Applications

Harper Adams University College, a leading agricultural university in Shropshire, have installed a Talbott's Biomass Generator.

Source:

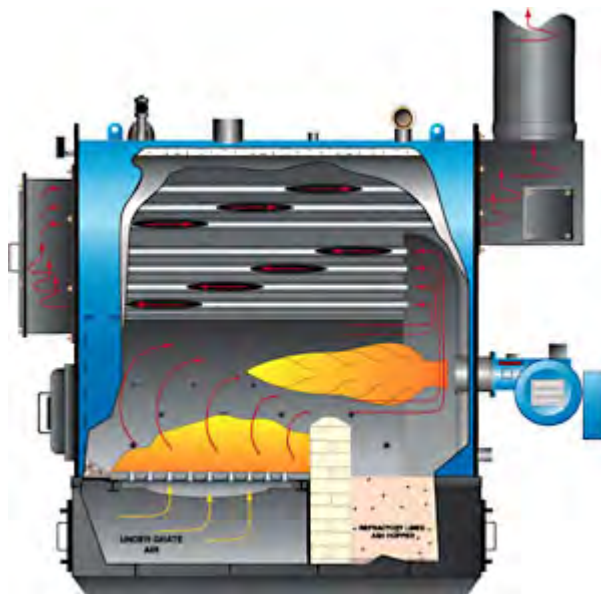
1. www.talbotts.co.uk

FIREBOX LPD HF¹⁹ USA, Commercial

Crop	Agricultural materials
Residue	Agricultural residue
Process	Gasification, combustion
Equipment	Boiler Firebox LPD HF
Main Product	Low pressure steam or hot water

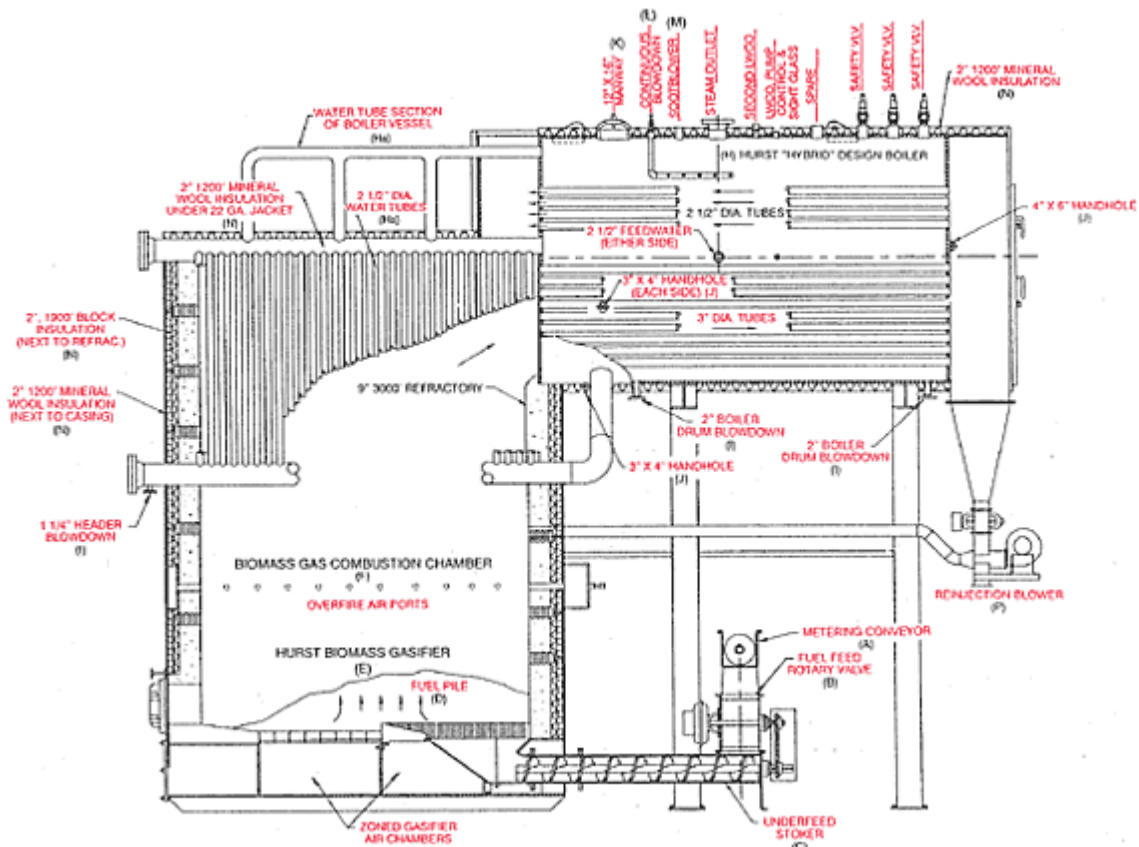
Production Capacity

The Firebox LPD HF design is suitable for applications to produce low-pressure steam or hot water in ranges from 3,450 - 20,700 lbs/hr (3.4 mm BTU - 20 mm BTU) output at 15-PSI steam or 30 PSI hot water.



¹⁹ <http://www.hurstboiler.com/biomass.htm>

Detailed Process Description



A. Metering Conveyor

Extra Heavy Duty Screw Conveyor with Variable Frequency AC Drive

B. Rotary Air Lock Valve

Limits Excess Air for Improved Combustion Control, Increased Efficiency and Emission Control

C. "Frederick" Solid Fuel Stoker

Manufactured since 1918, it is unsurpassed in the dependable stoking of solid fuels

D. Fuel Pile

The fuel pile, maintained by the stoker, covers all the grates for Improved Combustion Efficiency and Emission Control.

E. Gasifier

A combination of the "Frederick" stoker, combustion air system, and lower combustion chamber. The Hurst "Gasifier" vaporizes the volatile gasses from the solid fuel, driven by the remaining carbon on the grates.

F. Combustion Chamber

Combustion Air is mixed with the volatile gas created by the gasifier and burned in this area of the furnace.

G. Combustion Air System

Two blowers, one under fire and one over fire, furnishes and controls the volume of air entering the Gasifier and Combustion Chamber. All above work in concert to reduce solid fuels into usable heat energy utilizing the most reliable system yet devised. Our "cruise control" system orchestrates the operation of each to match the steam load and maintain efficient combustion.

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J. Handhole

The waterside openings are located in the most effective positions. The lower hand holes offer far better access for both clean out and inspection.

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L. Continuous Blowdown

M. Soot Blower

Fixed zone

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Liberal and easy accessible gas turn around area. No large refractory doors or wet back to work around.

P. Reinjection Blower

Continuously cleans rear smoke box.

Q. Skids and Support Structure

Unit is skid mounted with rear supports for easy handling and set-up.

Operation and Maintenance Requirements

5. Ash removal is a manual operation.
6. The company stocks replacement parts for the boilers and other major competitors' boilers as well. Manufacturing facility is in Coolidge, GA, supports parts center with the latest technology and competitive rates, offering shipping with Emory, DHL, Fed Ex and "UPS On Line Shipping / Tracking" for speedy delivery of critical parts orders to any facility in a timely fashion.

Examples of Real Life Applications

Commercial use FIREBOX LPD HF Highway 319 N. Coolidge, GA
31738

Supplier

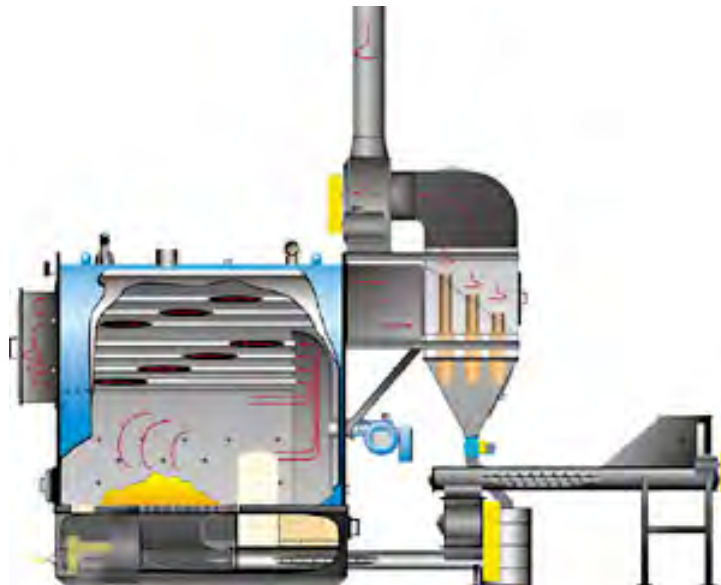
Hurst Boiler and Welding Co., Inc.

FIREBOX LPD UF²⁰
USA, Commercial

Crop	Agricultural materials
Residue	Agricultural residue
Process	Gasification, combustion
Equipment	Boiler Firebox LPD UF
Main Product	Low-pressure steam or hot water

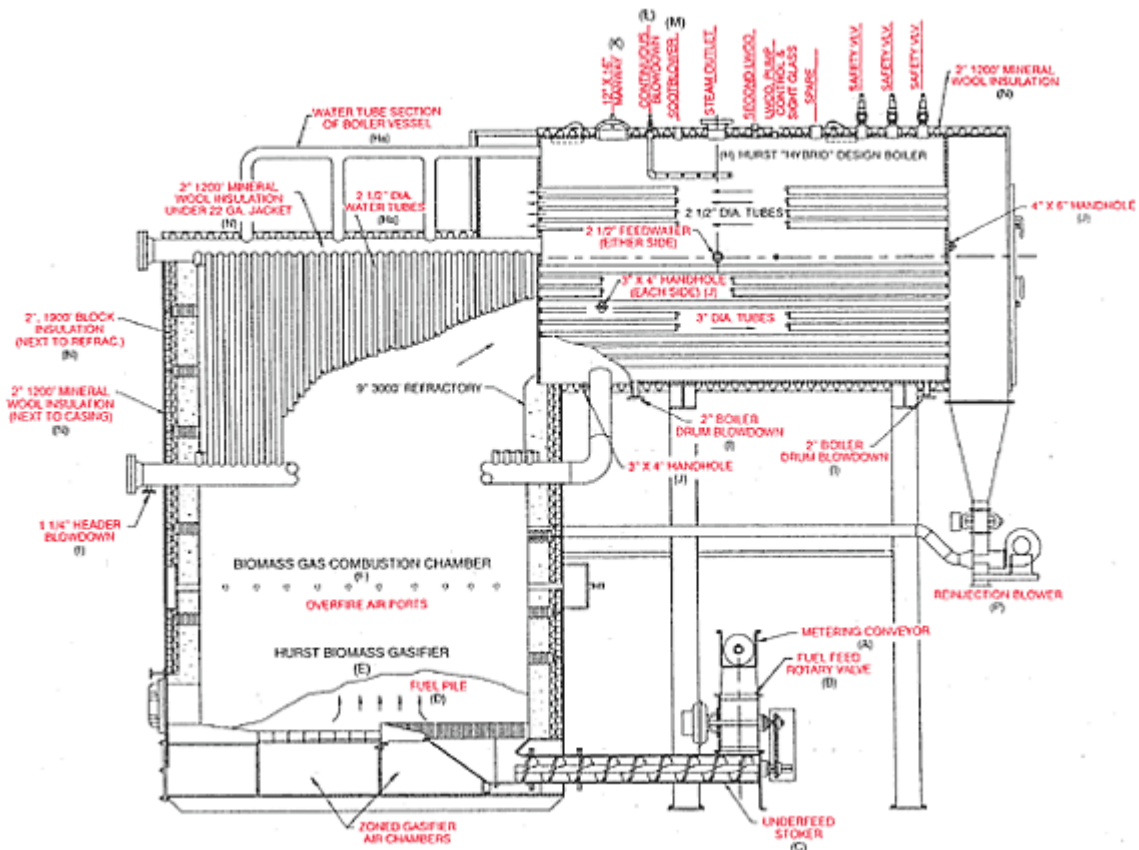
Production Capacity

The Firebox LPD UF design is suitable for applications to produce low-pressure steam or hot water in ranges from 3,450 - 20,700 lbs/hr (3.4 mm BTU - 20 mm BTU) output at 15-PSI steam or 30 PSI hot water.



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Examples of Real Life Applications

Commercial use FIREBOX LPD UF Highway 319 N. Coolidge, GA 31738

Suppliers

Hurst Boiler and Welding Co., Inc.

Fibrowatt Technology producing Electricity from Poultry Litter and Agricultural Waste U.S.A., Commercial

Crop	Alfalfa, Corn, Rice and poultry litter
Residue	Straw, Residues
Process	Combustion
Equipment	Boiler, Conveyor, Furnace, Condenser, Turbine
Main Product	Electricity
By-Product	

Technical Description of Technology

Fibrowatt has 15 years of operating experience using a proven technology that supplies enough electricity from three plants in the United Kingdom to serve 150,000 homes. Fibrominn generates enough electricity to serve 40,000 homes. Through long-term contracts and spot market purchases, Fibrowatt obtains poultry litter from surrounding farms. The process begins with poultry house cleaning, then the poultry litter is transported in tightly covered trucks to a fuel storage building, where jobs once operational (30 on-site jobs, 60 in litter transportation, and 10 at the ash fertilizer plant), and an economy boosted by increased local wages, spending, and tax revenues.

The technology used by Fibrowatt has been well proven by the management team in the three plants which they developed in the United Kingdom in the 1990s. Those plants, which have now been sold to a new owner, were the world's first three poultry litter fueled power plants. Over the past 15 years, they have turned more than seven million tons of poultry litter and other biomass into enough electricity to serve 150,000 British homes. Today, Fibrowatt is introducing its proven technology in select communities around the United States and continually improving upon its processes.

Detailed Process Description

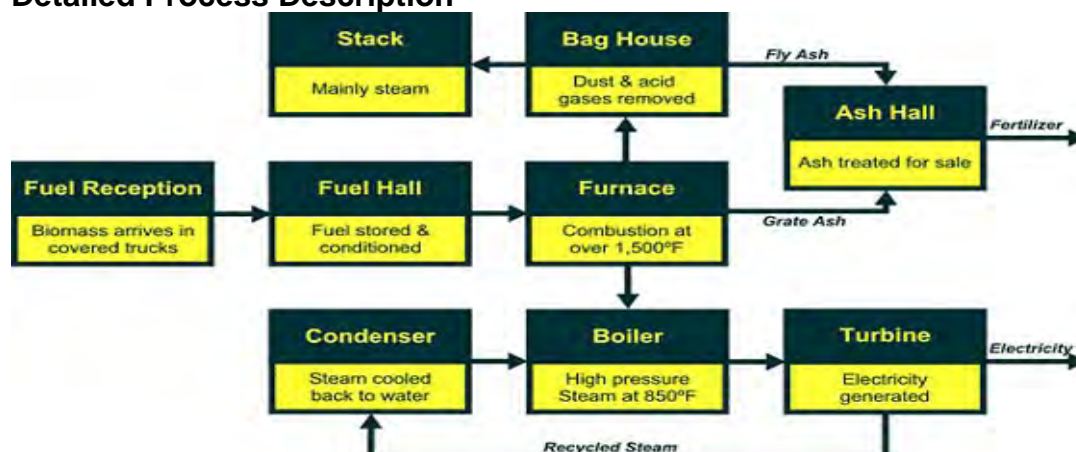


Figure 1. Schematic Diagram of Fibrowatt Technology

1. The Fibrowatt operation starts on the farm, where poultry house cleaning and litter removal are coordinated with the farmer.
2. Poultry litter is transported in tightly covered trucks on pre-arranged routes to the plant's fuel storage building. Truck routing is designed to minimize the biosecurity risk to existing poultry operations and reduce truck traffic impact on local communities.
3. Trucks unload the litter within a specially designed fuel storage building, which typically holds five to ten days' worth of fuel. The building is kept at negative pressure to prevent the escape of odors and, as a result, odors are undetectable beyond the plant site's boundaries.
4. From the fuel storage building, fuel travels on a conveyor system to the boiler. Fans draw air from the storage building into the boiler, where the litter is combusted at more than 1,500°F, ensuring the destruction of pathogens and complete combustion.
5. Water is heated in the boiler to produce high-pressure, high-temperature steam, which drives a turbine and generates electricity.
6. Renewable energy from poultry litter and other biomass, unlike fossil fuel-generated energy, results in no new carbon dioxide releases. Because Fibrowatt plants utilize a clean-burning fuel and advanced pollution-control equipment, the plants meet strict limits for each of the major gases emitted by the combustion process. Air emissions are regulated and monitored by a Continuous Emissions Monitoring System (CEMS) that logs and reports on emission performance.
7. Fibrowatt sells its renewable energy to electricity providers. The Fibrominn plant produces enough green electricity to serve 40,000 homes.
8. When poultry litter is combusted to produce electricity, a nutrient-rich by-product is produced in the form of ash. Fibrowatt plants recover this ash for processing. The fertilizer can be used to fertilize row crops, provide nutrients to managed forest farms, and in various other ways.

Main Products

Electricity

Environmental Considerations

Fibrowatt is the only experienced developer of power plants fueled by poultry litter and other agricultural biomass in the world. Its technology results in a variety of positive environmental impacts, including using locally abundant biomass, producing renewable energy, preventing over-application of poultry litter and recycling valuable nutrients.

Biomass used by the technology include:

- animal waste and bedding (such as poultry litter)
- dedicated energy crops
- agricultural by-products

- crop residues (such as alfalfa stems and corn residues)
- wood and wood wastes
- grasses

Investment and Operating Cost

Communities with Fibrowatt plants benefit from an average of several hundred-construction jobs, 100 fulltime jobs once operational (30 on-site jobs, 60 in litter transportation, and 10 at the ash fertilizer plant), and an economy boosted by increased local wages, spending, and tax revenues.

Examples of Real Life Applications

Minnesota: Fibrominn completed
 North Carolina: Projects under development
 Arkansas: Project under development
 Mississippi: Fibromiss under development
 Maryland: Fibroshore under development

Supplier:

Pennsylvania headquarters
 Fibrowatt LLC
 One Summit Square, Suite 200
 1717 Langhorne-Newtown Road
 Langhorne, PA 19047
 Phone: 267/352-0014
 Fax: 267/352-0035
 E-mail: info@FibrowattUSA.com

Kasia Wieronski, 267/352-0014
 Fibrominn - Minnesota
 Fibrominn, LLC
 900 Industry Drive
 PO Box 265
 Benson, MN 56215
 Telephone: (320)843-9013
 Fax: (320)843-9014

Sources:

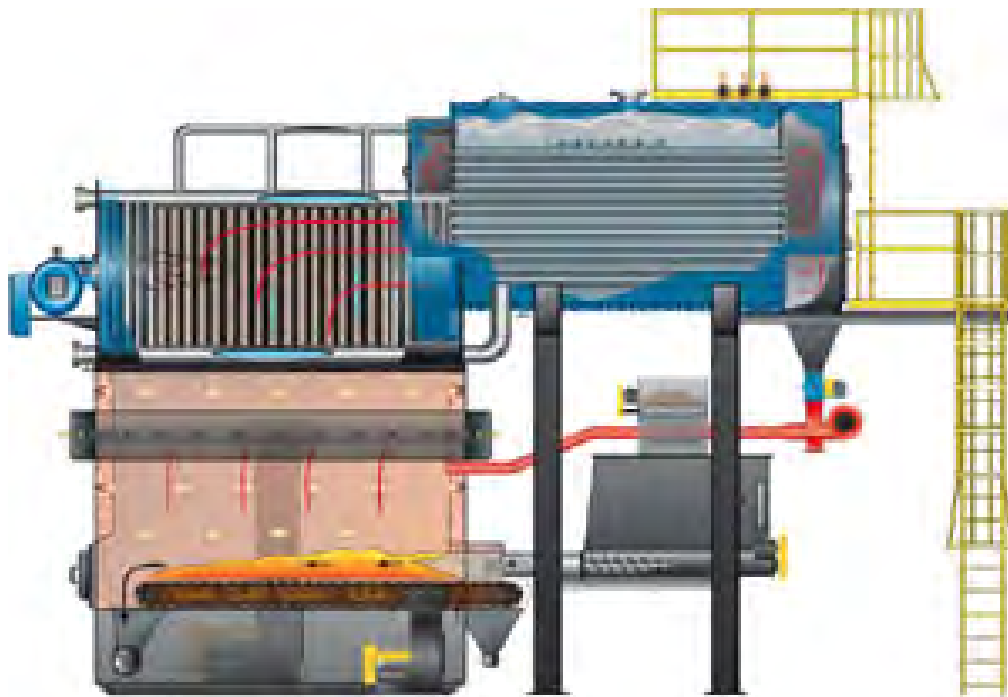
1. <http://www.fibrowattusa.com/index.cfm>
2. <http://www.fibrowattusa.com/cm/pdfs/fibrowatt.pdf>

HYBRID CG²¹ USA, Commercial

Crop	Agricultural materials
Residue	Agricultural residue
Process	Gasification, combustion
Equipment	Boiler Hybrid CG
Main Product	High pressure steam or hot water

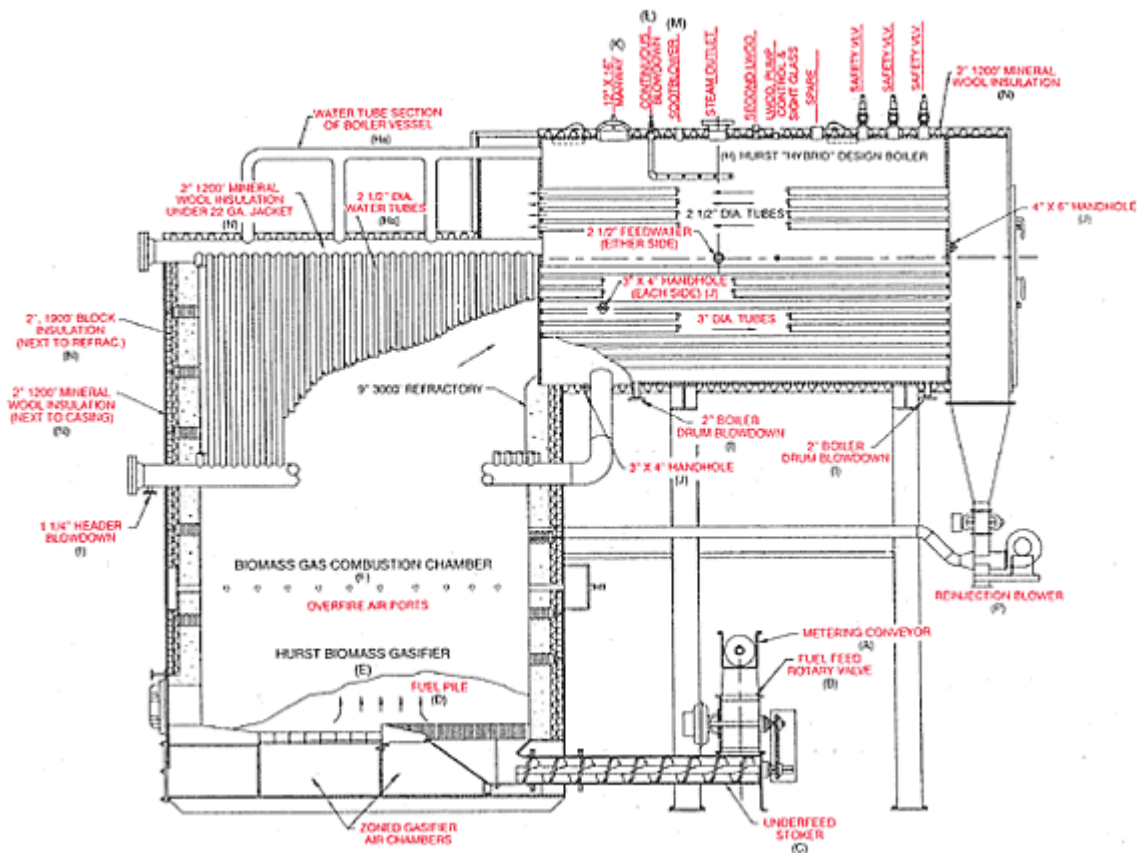
Production Capacity

The Hybrid CG design is suitable for applications to produce high pressure steam or hot water in ranges from 3,450 - 60,000 lbs/hr (3.4 mm BTU - 60 mm BTU) output from 100 up to 400 PSI.



²¹ <http://www.hurstboiler.com/biomass.html>

Detailed Process Description



A. Metering Conveyor

Extra Heavy Duty Screw Conveyor with Variable Frequency AC Drive

B. Rotary Air Lock Valve

Limits Excess Air for Improved Combustion Control, Increased Efficiency and Emission Control

C. "Frederick" Solid Fuel Stoker

Manufactured since 1918, it is unsurpassed in the dependable stoking of solid fuels

D. Fuel Pile

The fuel pile, maintained by the stoker, covers all the grates for Improved Combustion Efficiency and Emission Control.

E. Gasifier

A combination of the "Frederick" stoker, combustion air system, and lower combustion chamber. The Hurst "Gasifier" vaporizes the volatile gasses from the solid fuel, driven by the remaining carbon on the grates.

F. Combustion Chamber

Combustion Air is mixed with the volatile gas created by the gasifier and burned in this area of the furnace.

G. Combustion Air System

Two blowers, one under fire and one over fire, furnishes and controls the volume of air entering the Gasifier and Combustion Chamber. All above work in concert to reduce solid fuels into usable heat energy

utilizing the most reliable system yet devised. Our “cruise control” system orchestrates the operation of each to match the steam load and maintain efficient combustion. All above work in concert to reduce solid fuels into usable heat energy utilizing the most reliable system yet devised. Our “cruise control” system orchestrates the operation of each to match the steam load and maintain efficient combustion.

H. “Hybrid” Design Boiler

Originally built in Germany, the “Hybrid” design is unequalled in the heat recovery from solid fuels.

Ha. Water Tube Section

The watertube section of the “Hybrid” boiler allows for abundant radiant heating surface. This allows for quicker recovery and more efficient heat transfer than in the typical firetube boiler.

Hb. Fire Tube Section

The fire tube section of the “Hybrid” boiler allows for greater water volume and thermal reserve than the typical water tube boiler. Quick response with the additional capacity to handle spike loads is the result. In addition, the two pass design increases gas velocity and efficiency and a cleaner boiler result.

Hc. Steam Space

The fire tube section of the “Hybrid” also allows for several times the steam space of a typical boiler. The larger steam release surface is calmer, reducing carry over of unevaporated water. The resulting drier steam also reduces system scaling. In addition, dry steam helps eliminate unnecessary extra condensate. Energy and fuel are saved.

I. Boiler Blowdown

J. Handhole

The waterside openings are located in the most effective positions. The lower hand holes offer far better access for both clean out and inspection.

K. Manway

L. Continuous Blowdown

M. Soot Blower

Fixed zone

N. Insulation And Jacketing

2’ High Density fiberglass insulation and 22 ga. zinc coated metal jacket.

O. Rear Smoke Box

Liberal and easy accessible gas turn around area. No large refractory doors or wet back to work around.

Operation and Maintenance Requirements

9. The new HBC chain grate-type stoker system permits a wide range of biomass fuels with high ash contents to be combusted in an efficient manner with the added advantage of automatic de-ashing.
10. The company stocks replacement parts for the boilers and other major competitors' boilers as well. Manufacturing facility is in Coolidge, GA, supports parts center with the latest technology and competitive rates, offering shipping with Emory, DHL, Fed Ex and "UPS On Line Shipping / Tracking" for speedy delivery of critical parts orders to any facility in a timely fashion.

Examples of Real Life Applications

Commercial use Hybrid CG Highway 319 N. Coolidge, GA 31738

Suppliers

Hurst Boiler and Welding Co., Inc.

BTG Flash Pyrolysis Netherlands, Commercial

Crop	Rice, Olives, Switchgrass
Residue	Wood residues, straw, husks
Process	Pyrolysis
Equipment	hopper feeder, stack, heat exchanger pyrolysis reactor, rotating cone reactor
Main Product	Oil, gas and char

Technical Description of Technology

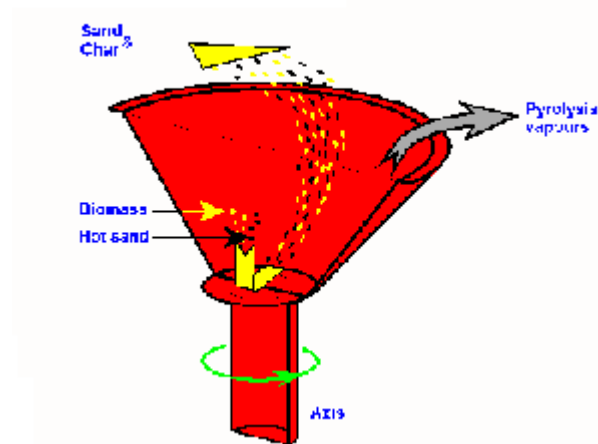


Figure 1. Rotating Cone Reactor

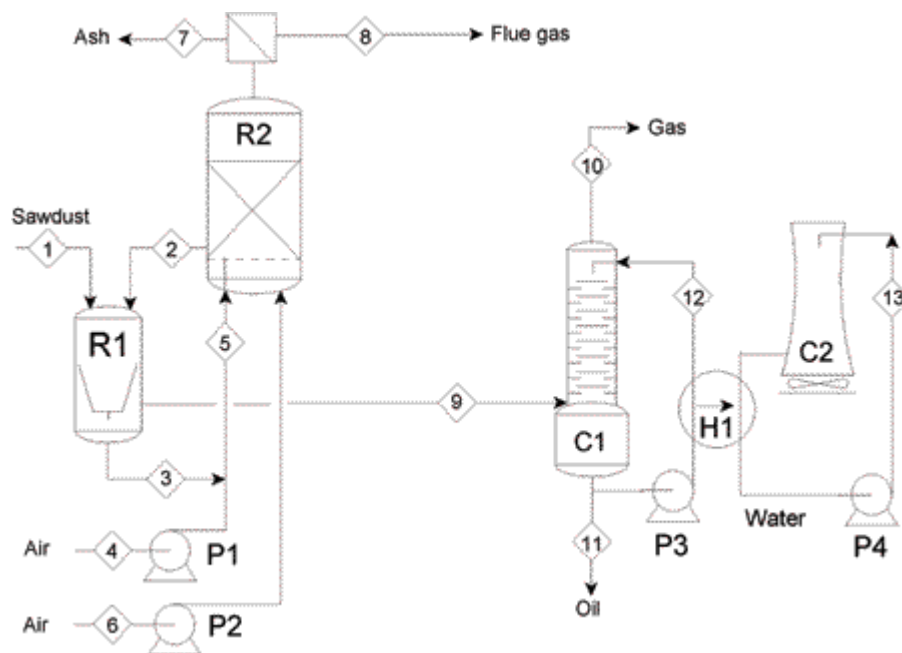
BTG's fast pyrolysis technology is based on the rotating cone reactor. It is a proven gas-solid contactor which has been developed at the University of Twente (Chem.Eng. Sci., 5109, (1994)). A schematic representation of the reactor is presented in the figure above. Biomass particles at room temperature and hot sand particles are introduced near the bottom of the cone where the solids are mixed and transported upwards by the rotating action of the cone. In this type of reactor, rapid heating and a short gas phase residence time can be realized.

Fast heating of biomass will prevent char forming reactions. In this mode, 75 wt.% bio-oil and only 15 wt.% char and gas are produced as primary products. Rapid removal of the pyrolysis vapours from the hot reactor enclosure ensures that less than 10 wt.% bio-oil is lost due to cracking reactions. Since no "inert" carrier gas is needed (unlike fluidized bed pyrolysis), the pyrolysis products are undiluted. This undiluted and hence small vapour flow results in downstream equipment of minimum size. Consequently, the capital costs of the complete unit are minimal.

In mechanical terms, the reactor technology is remarkably simple and robust. The rotational speed of the cone is only 300 rpm and after more than 1000 hours of operation in the current 250 kg/h pilot plant signs of abrasion or wear are absent

Scaling up of the rotating cone reactor is possible by increasing its diameter. For capacities, which require a cone diameter larger than 2 meters, stacking of multiply cones on a single axis leads to the lowest investment costs. This conventional approach is also encountered in centrifugal disk separators or rotating disks contactors. With these options all pilot plant capacities between 2 and 100 ton/hr can be served.

Detailed Process Description



Biomass particles are fed near the bottom of the pyrolysis reactor together with an excess flow of hot heat carrier material such as sand, where it is being pyrolysed. The produced vapours pass through several cyclones (not shown) before entering the condenser, in which the vapours are quenched by re-circulated oil. The pyrolysis reactor is integrated in a circulating sand system composed of a riser, a fluidized bed char combustor, the pyrolysis reactor, and a down-comer. In this concept, char is burned with air to provide the heat required for the pyrolysis process. In this case the plant is self-sustaining. Oil is the main product; non-condensable pyrolysis gases are currently flared-off, but application in a gas engine is foreseen. Excess heat can be used for drying the feedstock.

Main Products

Gas, bio-oil and char

Operation and Maintenance Requirements

Before processing organic materials in a fast pyrolysis plant, the feedstock must have the following requirements:

particle size < 6 mm,
moisture content < 10 wt.%

Environmental Considerations

Bio-oil can substitute for fuel oil or diesel in many static applications including boilers, furnaces, engines and turbines for electricity generation. The gases 10 wt.% can be fired in a boiler or in a gas engine. Finally, the char 15 wt.% may be combusted in the pyrolysis unit to drive the process auto-thermally. Only the ash is left as a waste stream.

Other advantages include:

1. Bio-oil is cleaner than biomass.
2. The ash content in bio-oil is a factor 100 lower than biomass.
3. Minerals like K, Cr, and Cu remain in the char.
4. The cost of bio-oil production is relatively low due to the mild conditions.

Example of Real Life Application

Aston University (UK), BHF-IWCT (GE), Wellman (UK), KARA (NL), Ormrod Diesels (UK)

Supplier

BTG biomass technology group BV
R&D Department
Pantheon 12
7521 PR Enschede
The Netherlands
Tel. + 31-53-4862287
Fax +31-53-4325399
E-mail: wagenaar@btgworld.com
Web: www.btgworld.com

Heat and Steam from Sugarcane Leaf and Bagasse India, Commercial

Crop	Sugar cane
Residue	Bagasse and leaf
Process	Gasification
Equipment	Gasification system
Main Product	Heat and Steam
By-Product	

Technical Description of Technology

²²GASIFICATION SYSTEM DESIGN

Certain critical engineering design norms of the gasification system were first developed on a laboratory-scale model and were then validated on a bench-scale model 6, 7 . These norms were then used to design a full-fledged commercial scale system with a thermal output of 1080 MJ h⁻¹ . This system (presently installed in the NARI campus) is seen in Fig. 1. It comprises of a reactor, a gas conditioning system, a biomass feeding system and the instrumentation and controls. A schematic diagram of this system is shown in Fig. 2. The salient features of these components are given below.



Fig 1.



Fig. 3.

²² <http://nariphaltan.virtualave.net/Gasifier.pdf>

a. **Reactor** : This was a downdraft, throatless and open-top reactor with an internal diameter of 75 cm and an active bed height of 1.25 m. It was designed for a heavy-duty cycle of 7500 hour per year operation. High temperature resisting firebricks conforming to IS 8 grade were used for the hot face followed by a cold face insulation.

b. **Gas conditioning system** : A completely dry dust collection system eliminated altogether the problem of wastewater. This consisted of a high temperature char/ash coarse settler and a high efficiency cyclone separator. A specifically designed high temperature resisting induced-draft fan 3 ensured that the entire system is under negative pressure so that in the event of leaks, outside air got sucked into the system, but the combustible gas did not leak out. Thus, this design is very environment-friendly. The char-ash from the coarse settler and the cyclone was collected in barrels and emptied in an ash pit once every forty-five minutes. This char-ash which typically has a gross calorific value of 18.9 MJ kg⁻¹ can be briquetted to form an excellent fuel, or can be used as a soil conditioner 8, 9 .

c. **Biomass feeding system** : This consisted of a scraper drag-out conveyor and a hopper to convey the biomass fuel from the storage pile to the reactor. The conveyor was completely enclosed.

d. **Instrumentation and Control System** : A Programmable Logic Controller (PLC)-based control system seen in Fig. 3 was designed to take automatic corrective actions under certain critical conditions. Thus, the biomass feeding and ash removal rates were fully controlled by this system. Besides, it also helped the operator in trouble-shooting by monitoring temperatures at various critical points in the gasification system. Automatic burner sequence controllers were provided for ignition of the producer gas.

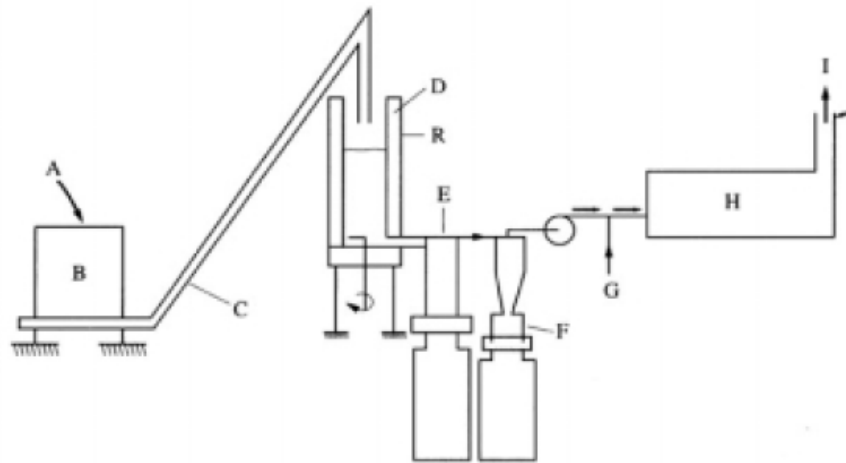


Fig. 2. Schematic diagram of sugarcane leaf-bagasse gasification system: A, biomass from storage piles; B, hopper; C, conveyor; D, refractory; E, char collector; F, cyclone; G, air; H, furnace (1080 MJ h^{-1}); I, chimney; R, reactor.

The gasification system was extremely simple to operate. A cold start took about ten-fifteen minutes whereas a hot start was effected in less than five minutes. Only two operators per shift of eight hours were required to operate the system, including the fuel and ash handling operations.

3. FUEL CHARACTERISTICS

The gasification system was successfully tested on sugarcane leaves and bagasse, sweet sorghum stalks and bagasse, bajra stalks etc. The physical properties of sugarcane leaves and bagasse under the actual operating conditions of the gasifier are given in Table 17 .

Investment and Operating Cost

The economic analysis of the system was evaluated both at its rated capacity of 1080 MJ h^{-1} and at an output level of 675 MJ h^{-1} which was usually required during the field tests. The data used for this analysis are given in Table 5.

TABLE 5 : ECONOMICS OF THE NARI GASIFICATION SYSTEM

Economic data (Gasifier rating = 1080 MJ h⁻¹)	
1. Cost of the gasifier system	: Rs. 5,25,000 (1 US \$ = Rs. 31) (1995 prices)
2. Civil construction cost	: Rs. 25,000
3. No. of intended hours of operation	: 7500 hours year ⁻¹
4. Depreciation	: 20% per annum by straight-line method
5. Interest	: 18% per annum annualized over 5 years
6. Wages + Salaries	: 2 persons/shift x 3 shifts/day x 365 days/ year x Rs. 50/person/day
7. Maintenance cost	: 20% of the capital cost spread over 5 years
8. Electricity cost	: 6 kW x Rs. 2.5 kWh ⁻¹
9. Biomass consumption	: 118 kg GJ ⁻¹

Table 6 gives the energy cost for a net landed biomass cost of Rs. 1,000 T⁻¹ (dry). The costing for other biomass prices is given in Fig. 5.

TABLE 6 : ENERGY COST DELIVERED TO THE FURNACE (1995 prices) (1 US \$ = Rs. 31)

A. Fixed Cost Components	Rs./year	
1. Depreciation	1,10,000	
2. Interest	53,750	
3. Maintenance	22,000	
4. Wages + Salaries	1,10,000	
5. Electricity	1,12,500	
Total fixed cost, Rs./year	4,08,250	
ENERGY COST, Rs./GJ	Gasifier output	
	675 MJ h⁻¹	1080 MJ h⁻¹
1. Fixed cost, Rs./GJ	79.6	50.4
2. Fuel cost, Rs./GJ (@ Rs. 1000/T)	118.0	118.0
TOTAL ENERGY COST, Rs./GJ	197.6	168.4
Light Diesel Oil (LDO) Cost, @Rs.7.5/l	Rs./GJ 280.3	

Fig. 5 shows that the system is economically attractive if the biomass cost (dried, sized and landed cost at the gasifier site) is less than Rs. 1,100 T⁻¹ (dry) when the LDO price is Rs. 7.51⁻¹ and when the

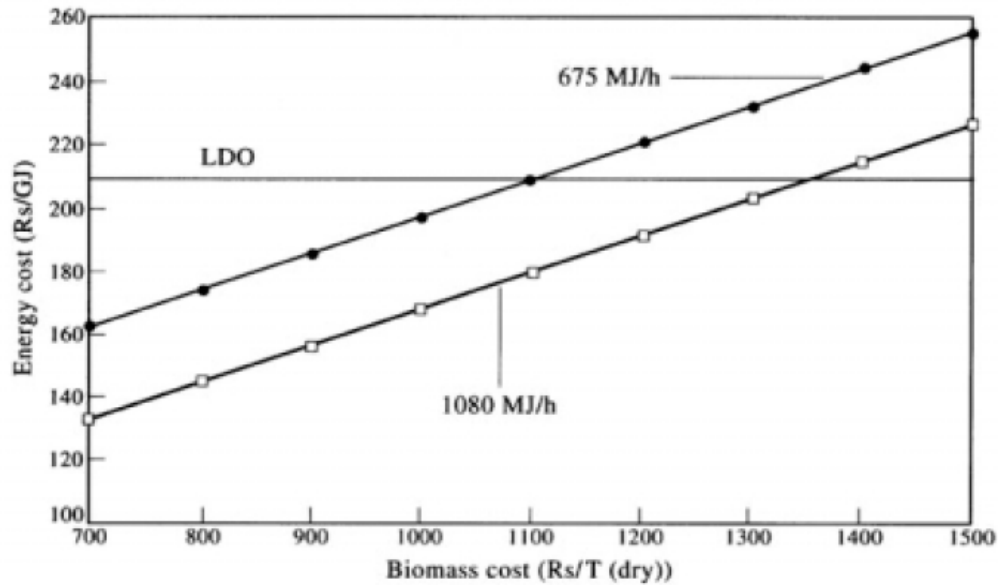


Fig. 5. Economics of the gasification system.

gasifier system is operating at 675 MJ h⁻¹. However, if the gasifier system operates at its rated capacity of 1080 MJ h⁻¹, the economics is attractive even for biomass cost of Rs. 1350 T⁻¹ (dry).

Data collected over two years in a sugarcane growing area show that the landed, sized and dried cost of sugarcane leaves is Rs. 900-1100 T⁻¹ if the material is procured from within a 20-30 km radial distance⁹. For industries located in such areas, the gasifier system can effect considerable savings in their fuel oil costs. Further, larger-scale units of capacities upto 3600 MJ h⁻¹ can be designed based on the engineering data generated on the present system.

Examples of Real Life Applications

Country: India

Level of application: Commercial

Supplier:

Nimbkar Agricultural Research Institute (NARI).

P.O. Box 44, PHALTAN-415523, Maharashtra, INDIA

E-mail : nariphaltan@sancharnet.in

Dan Chang Bio-energy Project²³ Thailand, Commercial

Crop	Sugarcane
Residue	Bagasse
Process	Combustion
Equipment	Steam turbo generator, vibrating grate boiler
Main Product	Steam and electricity requirements of the sugar mill
By-Product	24 MW of excess electricity to be exported to the national grid through a firm contract of 21 years

Production Capacity

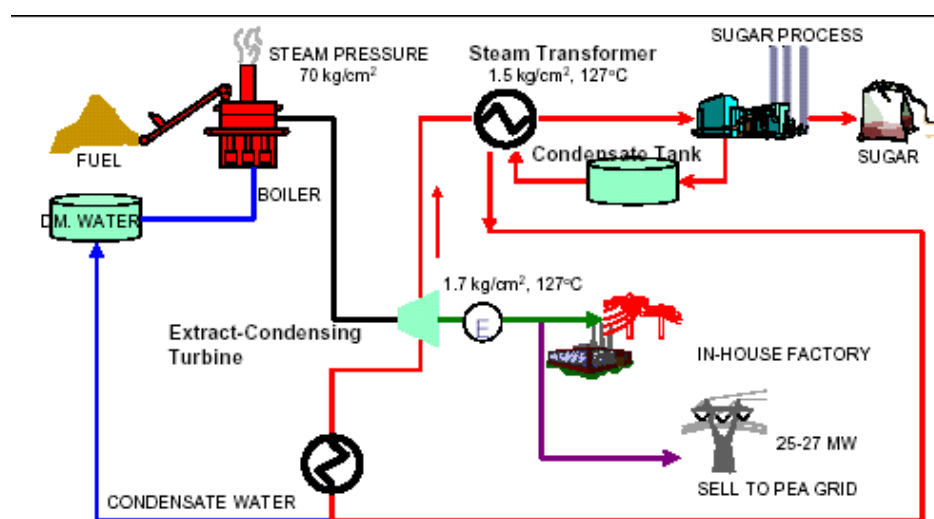
- a 41 MWe extraction condensing steam turbo-generator;
- two vibrating grate boilers with an hourly capacity of 120 tonnes of steam at 68 bar (a) and 510oC each

Detailed Process Description

The new 41 MWe bagasse-fired cogeneration project is designed not only to provide the steam and electricity requirements of the sugar mill but also to produce 24 MW of excess electricity to be exported to the national grid through a firm contract of 21 years.

The project consists of the following components:

- a 41 MWe extraction condensing steam turbo-generator;
- two vibrating grate boilers with an hourly capacity of 120 tonnes of steam at 68 bar (a) and 510oC each.



²³ <http://www.cogen3.net/doc/articles/CleanandefficientbiomassCogeneration.pdf>

Price of Machine The total investment cost for the project is around Euro 35.5 million, excluding civil works and building foundation. The expected payback period is 5 years after commissioning.

GHG Emission Reduction Potential

The total Green House Gas (GHG) Mitigation by implementing this bagasse-fired project is expected around 278,610 tonnes of CO2 equivalent per year.

Examples of Real Life Applications

Implemented since 2004 Dan Chang Bio-Energy project Thailand

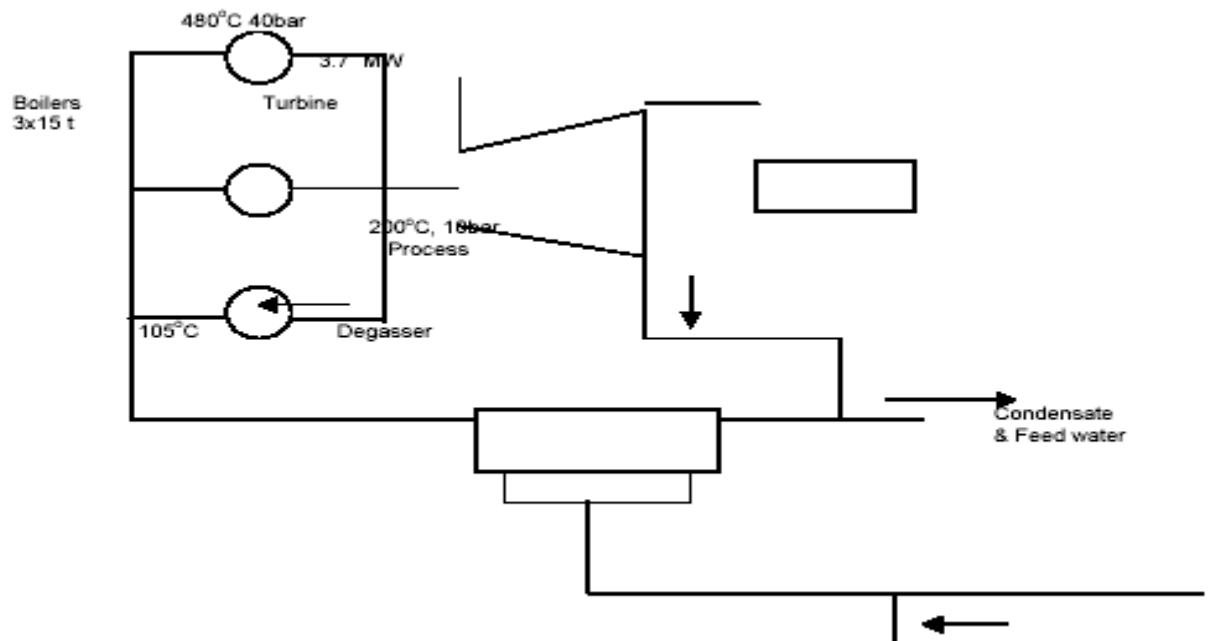
Biomass-based Cogeneration Plant Tanzania, Commercial

Crop	Sugar Cane
Residue	Bagasse
Process	Cogeneration
Equipment	
Main Product	Fuel

Technical Description of Technology

The simplest plant setup of a Bagasse Cogeneration plant (see Figure 1) involves the installation of a boiler producing higher steam pressure than required for the process. This steam is passed through a steam turbine where some of the energy is used to generate mechanical power for driving an alternator for electricity. The steam exits the turbine at a reduced pressure and is then returned to the boiler as condensate or hot water. The primary objective of the energy system is the production of steam hence the electricity that is produced is governed by the demand for process steam. In some cases especially in sugar mills the electricity becomes a primary product when the steam is excess to requirements such as is the case after milling season. The turbine would then be a condensing one where the steam is returned to the boiler without having to pass through the process. Under these circumstances the plant operates as a bagasse fired power station.

Figure 1. Structure of a Bagasse Cogeneration Plant



Main Products:

The plant provides its own source of energy for sugar production in the form of bagasse. If well planned, the bagasse can relieve the pressure on the limited resources of fuel and fibre available in Tanzania. From the experiences in sugar industry (Mtibwa Sugar Estate- Cogeneration Workshop in SADC, November 2003), if processed in efficient manner, 1 hectare of cane field can yield 10 tonnes of valuable fibre for fuel, paper and board, 10 tonnes of food products including sugar, 1 m³ of alcohol and 2 tonnes of fertilizers.

Job Potential:

In Tanganyika Planting Company (TPC) in Tanzania, the factory has a total of 16,000 hectares of land out of which about 6,100 hectares is under cane cultivation. The tonnage of cane at present is about 604,000 tonnes but the field potential in cane production is more than 775,000 tonnes. Assuming that all seasonal employees work in the field during production period then:

636 persons cultivate 604,000 tonnes;

Therefore 775,000 tonnes will require $(775,000 \times 636) / 604,000 = 816$ person;

636 persons generate 2.5 MW; 816 persons generate 12.9 MW;

Therefore $(816 - 636)$ persons generate $(12.9 - 2.5)$ MW ;

180 persons generate 10.4 MW > 17 person/MW.

Therefore cogeneration can generate more than 17 jobs (persons/MW).

This concludes that the job creation potential is higher in cogeneration than in conventional energy technology. Likewise, the potential for the enterprises creation is higher with cogeneration technology than the conventional energy, depending on the cogeneration technology employed.

Operation and Maintenance Requirements:

In order to generate electricity to cater only for the plant use, one boiler of capacity 90 tonnes MCR for steam generation and one turbo alternator (back pressure type) of 14 MW for power generation should be installed. Also the pressures and temperature should be raised to 45 bar and 430°C respectively. The total cost for this is estimated to be US\$ 28.5 million. On the other hand for further increase in electricity generation for exporting 7.6 MW to the national grid, one boiler of capacity 140 tonnes MCR for steam generation and one back pressure and condensing turbo alternator of 22 MW for power generation will be required. The temperature and pressure for the process will remain the same that is 430°C and 45 bar respectively. The cost for this is estimated to be US\$ 35.5 million.

Social Considerations

By utilization of this technology it would be possible for Tanzania to reduce its spending of foreign currency on import of petroleum fuels. In a longer time perspective this technology would make it possible to eliminate the constraints upon economic development imposed on Tanzania by the limited amount of foreign currency available for import of petroleum fuels.

The local society would benefit from increased economic independence, primarily by substitution of fuels purchased from the outside by fuels produced locally. This means that a larger fraction of local earnings are spent locally. The users of the technology would benefit from lower energy costs and improved security of supply.

Environmental Consideration

The options for increasing electricity generation in sugar factories have a positive environmental impact. The factory may contribute to the reduction of green house gas emissions by replacing fossil fuelled thermal power plants with biomass-powered plants. Compared to oil and coal fuels, biomass has much lower sulphur content. This reduces SO₂ emissions and lowers the risk of soil and water acidification. The ash content in biomass is lower than in coal, meaning fewer problems with ash disposal and leakage of heavy metals. Replacement of old boilers with more modern ones can be expected to reduce emissions, despite the fact that fuel through-put will be almost doubled.

Investments and Operating Cost

Depending on type of cogeneration, the investment cost ranges between 1,600USD/kW to 3,500 USD/kW installed. This can be easily proved by using the data available from one of our sugar factories in Tanzania, TPC in Kilimanjaro region. From the above, the cost for investment of a cogeneration plant of 13 MW is about 2,210 US\$/kW and that of 20.5 MW is about 1,730 US\$/kW.

Economic Instruments for Overcoming Barriers

At macro-economic level, cogeneration can reduce the growth of national debt as well as improve the national balance of payments by reducing the import of fossil fuels. Unfortunately cogeneration was not given due attention in the past national policy and planning.

Co-generation can be increasing gradually, that is in modular manner. This may enable the projects to be financed locally. Also this could help to gain more experience from other factories within the region.

Advantages to Developing Countries

Cogeneration can be implemented in rural areas with women participation. The sugar factories buy sugar cane from some surrounding small-scale producers. Both men and women may participate in growing this plant. They can be employed by sugar cane small scale producers in planting, weeding and harvesting the sugar cane plant. Also those with transport may be hired to transport cane to the factory. This increases the income to rural people. Such activities could reduce rural to urban migration.

Disadvantages to Developing Countries

1. Deterioration of some equipment due to old age. This requires frequent replacement of some spare parts which means more expenditure in forex for the spares whose raw materials like stainless steel, are not locally available.
2. There is a shortage of forex to service high technology and very sophisticated equipment. This means there is a need to shop around for technological levels that are manageable within the region.
3. Non-availability of credit facilities in the country makes it difficult to set up more cogeneration systems.

Examples of Real Life Applications

Kilombero Sugar Company
Morogoro, Tanzania

Mtibwa Sugar Estate
Morogoro, Tanzania

Bagasse Tanganyika Planting Company
Kilimanjaro, Tanzania

Bagasse Kagera Sugar Company
Kagera, Tanzania

Bagasse Sao Hill Saw Mill , Iringa, Tanzania

Sugar Mill Bagasse Boilers²⁴ Uganda, Commercial

Crop	Sugarcane
Residue	Bagasse
Process	Combustion
Equipment	Bagasse Boiler
Main Product	Heat for sugar mill boilers

Production Capacity

Bagasse (moisture content of 50-55% water, and this is also the moisture content of the cane when it is fed into the boiler. None of the sugar factories in Uganda predry the bagasse before it enters the boiler. The ash content varies from 2.5-6%, and the season of the year and techniques of harvesting are determining the ash content. If the harvesting is done in terms of mechanical loading, the ash content increases, and this is also happening in wet weather because more mud etc. is following the canes into the process (Polzin, 2004).

Currently (2004) there are four boilers installed at Kakira Sugar Works. They have the

following technical specifications:

- Boiler 1: 24 tons of steam per hour
- Boiler 2: 22 tons of steam per hour
- Boiler 3: 22 tons of steam per hour
- Boiler 4: 24 tons of steam per hour

The boilers are all operating at 20 bar pressure, and a combustion temperature at 300 °C.

A fifth boiler will be ready July 1st 2004, and it will be operated at 30 t MCR.

There are two turbines at Kakira:

- Turbo Alternator 1: 3 MW and 18 bar pressure. The water rate is at 11 kg/kW
- Turbo Alternatio 2: 1.5 MW and 18 bar pressure. The water rate: 13 kg/kW

The boilers at Kinyara have the following specifications:

- Boiler number 1: 35 tons of steam per hour at 2350 kPa and 350 °C
- Boiler number 2: 35 tons of steam per hour at 2350 kPa and 350 °C.

There are two turbines installed at Kinyara, and they have the following specifications.

They both have 1 MW steam driven back pressure Allen turbines. The pressure is 2350

²⁴ Lars Petter Bingham, NTHU, Opportunities for Utilizing Waste Biomass for Energy in Uganda, 2004

Detailed Process Description

Kakira Sugar Works

The boilers are constructed for bagasse combustion. The bagasse is gravity fed into the combustion chamber through chutes at the top of the boilers. The primary and secondary combustion air is entering the combustion chamber through ports in the furnace walls. The combustion starts where the bagasse hits the surface pile.

Kinyara Sugar Works

Recently the boilers have been modified, and pinhole grates have been installed to improve the combustion process. These grates promote suspension firing of bagasse instead of pile burning which gives a much better heat release from the fuel (Jobling, 2004).

Generally the turbines are operated 46 weeks of the year. However, maintenance work is done to the machines every third week when they are turned off 16 hours each time. The turbines are operated at a load of 750 kW each. To handle peaks in the system there are diesel generating plants, which consist of one generator at 800 kW and one at 400 kW.

Examples of Real Life Applications

Commercial

Karika Sugar Works
Uganda

Commercial

Kinraya Sugar Works

Uganda

Brick Making²⁵ (Hoffman Kiln or Ring Kiln) Uganda, Commercial

Crop	Coffee
Residue	Husk
Process	Combustion
Equipment	Ring Kiln
Main Product	Heat for drying

Production Capacity

The dimensions of the kiln are quite large. Four of the chambers in the kiln are fired a day. The capacity of these four chambers are 2400 Maxpan blocks, 16 000 Mangolone tiles (roofing tiles) and 6000 Half bricks. The fuel consumption for this quantity is two 7 tons lorries filled with coffee husks. The exact capacity of these lorries are not measured, but estimated to 3-4 tons of coffee husks.

Detailed Process Description

The Hoffmann kiln is constructed in a ring. The main purpose of this design is to make it possible to recover the heat from the flue gases in the combustion process. This design makes it possible to use the hot flue gas to preheat and dry the bricks before they enter the hottest parts of the kiln. In the post combustion phase, the heat from the finished bricks are preheating and drying the newly entered bricks (Nturanabo2, 2001). The kiln is divided into different chambers, and the combustion process is taking place in one of these chambers at time. There are channels connecting the chambers, where hot air and flue gases are transporting heat through the kiln. The kiln is fired by coffee husks. The husks are fed automatically into the kiln from wholes in the ceiling of the kiln. The rate of fuel entering the combustion chambers is regulated by measurements of the temperature inside the kiln.

When the feeders of coffee husks are moved to the next chamber, the temperature in that chamber is approximately 700 °C. Then, when the fuel starts pouring in, the temperature rises from 700 °C towards 900 °C which is reached after 1.5 or 2 hours. When the feeding of coffee husks is stopped, it takes around 1.5 to 2 hours before the temperature drops to 700 °C. When the combustion zone are moved further away, the temperature will decrease further from 700 °C and reach lower levels until around 100 °C when the bricks are ready to be removed from the kiln (Kayando, 2004). The kiln is emptied and filled up again opposite the combustion zone, because this area is the temperature is at its lowest. In this way, the combustion zone is moving constantly around in the kiln, and the combustion has lasted continuously since the kiln was opened.

²⁵ Lars Petter Bingham, NTHU, Opportunities for Utilizing Waste Biomass for Energy in Uganda, 2004

Example of Real Life Applications

Commercial Use Hoffman Kiln
Road, Uganda

Uganda Clays Ltd. Entebbe



Figure 11: The entrance to one of the chambers in the Hoffmann kiln at Uganda Clays can be seen to the left. The right picture is showing the wholes in the ceiling of the kiln used to feed coffee husks into the kiln.

Coffee Husk Cement Kiln²⁶ Uganda, Commercial

Crop	Coffee
Residue	Husk
Process	Combustion
Equipment	Rotary Kiln
Main Product	Heat

Production Capacity

The consumption of coffee husks for that purpose is approximately 20 tons per day in 2003 (Norplan, 2003). No information is available on the number of operating days a year, but assumed that the factory produce 320 days (Kakira Sugar Works operates 320 days a year according to Polzin (2004)) a year, the total amount of coffee husks used is 6 400 tons.

²⁶ Lars Petter Bingham, NTHU, Opportunities for Utilizing Waste Biomass for Energy in Uganda, 2004

Detailed Process Description

Hima cement is utilizing coffee husks in their production process. Cement is produced from limestone, which is crushed and grinded. The materials are calcinated in a rotary kiln, where the so called clinker is produced. The clinker is cooled until it is mixed with gypsum. When the cement is finished it is milled, stored and bagged. The coffee husks are used in preheating of the lime.

Examples of Real Life Applications

Commercial

Hima Cement

Uganda

Aqueous Phase Reforming (APR)²⁷ USA, Commercial

Crop	Corn
Residue	Syrup
Process	Gasification, Aqueous Steam Reforming
Equipment	
Main Product	Electricity

Technical Description of Technology

The technology will be used for the first time to continuously produce electricity from a small 10-kilowatt generator at the company's facility in Madison. The unit is fueled by corn syrup, similar to the kind used by soft drinks manufacturers. The vast majority of hydrogen is currently made from fossil fuels -- oil, coal, and, most commonly, natural gas, through a process called steam reforming. In this process, a mixture of steam and methane is heated to temperatures above 800 degrees Celsius, and then reacts with a catalyst to produce hydrogen and carbon monoxide.

Although it's possible to use a similar process to generate hydrogen from biomass-derived ethanol, there are disadvantages in doing so. The high temperatures required and use of pressurized steam mean the conversion process only practical on the industrial scale. Virent's conversion process, which is called aqueous phase reforming (APR), avoids these problems by carrying out the reformation at relatively low temperatures and with liquids rather than steam. It means that there is no need to put as much energy into the system to make steam, and at the same time you're working with liquids, which have a higher energy density than gases for a given volume.

Furthermore, the process uses extremely active catalysts, which allow 15 times more hydrogen to be converted per gram of catalyst, compared with steam reforming. This efficiency allows 90 percent of the feedstock to be converted in the first cycle, and the rest to be recycled. As a result, Virent claims it's able to produce hydrogen for \$2-3 per kilogram -- competitive with natural-gas-derived hydrogen.

Examples of Real Life Applications

The technology will be used for the first time (2005) to continuously produce electricity from a small 10-kilowatt generator at the company's facility in Madison.

²⁷ http://www.technologyreview.com/read_article.aspx?id=16841

Suppliers**Virent Energy Systems, Inc²⁸.**

3571 Anderson Street

Madison , WI 53704

Phone:+1.608.663.0228

Fax: +1.608.663.1630

Email: info@virent.com

Webmaster: webmaster@virent.com

²⁸ <http://www.virent.com/ContactUs/contactus.html>

Shelled Corn as Fuel²⁹ USA, Commercial

Crop	Corn
Residue	Shelled Corn
Process	Combustion
Equipment	Stoves and boilers
Main Product	Heat

Technical Description of Technology

Burning shelled corn as a fuel can be a feasible way of dealing with the high prices of more conventional fuels such as fuel oil, propane, natural gas, coal, and firewood. Utilizing corn as a fuel does not compete with the food supply needed for nourishment throughout the world. While it is recognized that malnutrition is a serious global problem, the world is not experiencing a food production problem. Instead the world faces political challenges associated with providing infrastructure systems for food distribution and storage.

Contemporary agricultural systems can produce sufficient quality and quantity of food for the world's population, with additional resources available so that agricultural products can be used as fuel, pharmaceuticals, and chemical feedstocks.

Additional Information

[Heat Energy Content of Shelled Corn](#) — The combustion energy content of shelled corn is a critical factor in making energy comparisons of fuels.

[Corn Energy Equivalents](#) — This table provides a method of calculating how much shelled corn would be required to replace the fuel currently being used for heating.

[EnergySelector](#) — EnergySelector is a user-friendly decision-aide to easily compare the heating values available from any two energy sources.

[Shopping for a Corn-Burning Stove?](#) — Questions to ask when considering the purchase of a corn-burning stove.

[Locating a Supplier of Shelled Corn](#) — Do not purchase a corn-burning stove without first identifying a reliable supplier of shelled corn.

[Quality of Shelled Corn](#) — For best results, the quality of shelled corn burned in a corn-burning stove must be specified.

[Storage Requirements of Shelled Corn](#) — Proper storage of shelled corn is important for good performance of a corn-burning stove.

[Disposal of Corn Ash](#) — A plan for the proper disposal of corn ash needs to be developed before purchasing a corn-burning stove.

²⁹ <http://burncorn.cas.psu.edu/>



Environmental Considerations

Shelled corn is a fuel that can be produced within 180 days, compared to the millennia needed to produce fossil fuels.

Suppliers

For more information please contact:

Dennis Buffington
Professor of Agricultural and Biological Engineering
Penn State University
Email: dbuffington@psu.edu
814-865-2971 (Voice)
814-863-1031 (FAX)

MANUFACTURERS OF CORN-BURNING STOVES AND BOILERS

FOR RESIDENTIAL APPLICATIONS

Alternate Energy Solutions/Sedore Stoves USA
47909 County Road 37
Deer River, Minnesota 56636
218-246-2908
<http://www.sedoreusa.com>

Amaizablaze/Nesco, Inc.
P. O. Box 3498
Cookeville, TN 38502
931-372-0130
<http://www.cornstoves.info>

American Energy Systems, Inc.
150 Michigan Street SE
Hutchinson, MN 55350
800-495-3196
<http://www.hearthdirect.com>

America's Heat/LMF Mfg.
601 Woods Avenue
Lock Haven, PA 17745
800-582-4317
<http://www.americasheat.com>

Big M Manufacturing Co.
Box 319A
928 East 1090 N. Road
Taylorville, IL 62568
217-824-9372 Bixby Energy
9300 75th Avenue North
Minneapolis, MN 55428
877-500-2800
<http://www.bixbyenergy.com>

CANECO Manufacturing Inc.
Box 9042, Sub.40
London, ON
N6E 1V0 Canada
519-686-7298
<http://www.cornstove.ca>

CornGlo Industries, LLC
P.O. Box 548
3990 Highway 25E
Beanstation, TN 37708
865-993-4436
www.cornnglo.com

Corn King Furnaces
3332 Hosner Rd.
Dryden, Michigan 48428
810-796-9805
<http://www.cornkingfurnaces.com/>

Country Flame Technologies, Inc.
1200 E. Industrial Park Drive
Mt. Vernon, MO 65712
417-466-7161
<http://www.countryflame.com>

Dansons Group, Inc.
26319 Township Road 531
Acheson, Alberta
Canada T7X 5A3
877-303-3135
<http://www.dansons.com>

Eagle Manufacturing, Inc.
1120 East 2nd Street
Webster City, IA 50595
515-832-4655
<http://www.eaglemfginc.com>

Fahrenheit Technologies, Inc.
526 East 64th Street
Holland, MI 49423
616-392-7410
<http://www.fahrenheittech.com>

Golden Grain Corn Stove
P.O. Box 5000
Sterling, CO 80751
800-634-6097
<http://www.goldengrainstove.com>

Grain Stoves, Inc.
R.R. 3
Blyth, Ontario
Canada NOM 1HO
519-523-9897
<http://www.grainstovesinc.com>

Harman Stove Company
352 Mountain House Road
Halifax, PA 17032
717-362-1422
<http://harmanstoves.com>

HS-Tarm
5 Main Street, P.O. Box 285
Lyme, NH 03768
800-782-9927
<http://www.pelletboiler.com>

Ja-Ran Enterprises, Inc.
3541 Babcock Road
Lexington, MI 48450
810-359-7985
<http://www.ja-ran.com>

K-C Cornburners, Inc.
1433 Northstar Drive
Zumbrota, MN 55992
507-732-4666
<http://kccornburners.com>

Kernelburner
46304 Jeffery Street
Hartford, SD 57033
605-528-4700
<http://www.kernelburner.com>

Kozy Heat Fireplaces
204 Industrial Park Drive
Lakefield, MN 56150
800-253-4904
www.kozyheat.com

LDJ Manufacturing
1833 Hwy 163
Pella, IA 50219
866-535-7667
<http://www.ldj-products.com>

Lennox Hearth Products
1110 West Taft Avenue
Orange, CA 92865
714-921-6100
<http://www.earthstove.com>

Pinnacle Stove Sales, Inc.
1089 Highway 97 North
Quesnel, B. C.
Canada V2J 2Y3
250-992-5050
<http://www.pinnaclestove.com>

Quadra-Fire
Hearth & Home Technologies
1445 North Highway
Colville, WA 99114-2008
<http://www.quadrafire.com>

RJM Manufacturing, Inc.
1875 Olson Drive
Chippewa Falls, WI 54729
715-720-1794
<http://www.energyking.com>

SAR Biomass Energy Systems LLC
P.O. Box 203
Pocahontas IA, 50574
712-335-4616
www.sarcornfurnace.com

Sedore Multi-Fuel Stoves and Furnaces
P. O. Box 103
Oro, Ontario L0L 2X0
705-487-1921
<http://www.sedoremultifuelstoves.com>

Snow Flame, Inc.
4076 Haywood Road
Mills River, NC 28742
828-891-1006
<http://www.snowflame.com>

Thor Manufacturing LLC
1460 Timber Avenue
Hansell, IA 50441
641-257-4220
<http://www.thorfrostbuster.com>

United States Stove Company
108 Garner Road
Bridgeport, AL 35740
423-837-2100
<http://www.usstove.com>

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Lock Haven, PA 17745
800-582-4317
<http://www.americasheat.com>

Big M Manufacturing Co.
(A-Maize-Ing Heat)
Box 319A
928 East 1090 N. Road
Taylorville, IL 62568
217-824-9372

Corn King Furnaces
3332 Hosner Rd.
Dryden, Michigan 48428
(810) 627-9646
<http://www.thecornfurnace.com>

Eagle Manufacturing, Inc.
1120 East 2nd Street
Webster City, IA 50595
515-832-4655
<http://www.eaglemfqinc.com>

Golden Grain Corn Stove
P.O. Box 5000
Sterling, CO 80751
800-634-6097
<http://www.goldengrainstove.com>

HS-Tarm
5 Main Street, P.O. Box 285
Lyme, NH 03768
800-782-9927
<http://www.pelletboiler.com>

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3541 Babcock Road
Lexington, MI 48450
810-359-7985
<http://www.ja-ran.com>

K-C Cornburners, Inc.
1433 Northstar Drive
Zumbrota, MN 55992
507-732-4666
<http://kccornburners.com>

Kernelburner
25198 421st Ave.

Alexandria, SD 57311
605-239-4690
<http://www.kernelburner.com>

LDJ Manufacturing
1833 Hwy 163
Pella, IA 50219
866-535-7667
<http://www.ldj-products.com>

Pinnacle Stove Sales, Inc.
1089 Highway 97 North
Quesnel, B. C.
Canada V2J 2Y3
250-992-5050
<http://www.pinnaclestove.com>

Quality Manitoban Products
Box 398
Morris, MB Canada
204-746-6894
<http://www.topline-dist.com>

RJM Manufacturing, Inc.
1875 Olson Drive
Chippewa Falls, WI 54729
715-720-1794
<http://www.energyking.com>

SAR Biomass Energy Systems LLC
P.O. Box 203
Pocahontas IA, 50574
712-335-4616
www.sarcornfurnace.com

Solagen
33993 Lawrence Road
Deer Island, OR 97054
503-366-4210
<http://www.solageninc.com>

Thor Manufacturing LLC
1460 Timber Avenue
Hansell, IA 50441
641-257-4220
<http://www.thorfreezebuster.com>

Year-A-Round Corporation
110 West Lind Street

P.O. Box 2075, Mankato, MN 56002
800-418-9390
<http://www.year-a-round.com>

MANUFACTURERS OF CORN-BURNING STOVES AND BOILERS

FOR INDUSTRIAL APPLICATIONS
(500,000 BTU/HOUR AND LARGER)

Advanced Recycling Equipment, Inc.
850 Washington Road
St. Marys, PA 15857
800-611-6599
<http://advancedrecyclingequip.com>

RIMACO
P. O. Box 41
Beavertown, PA 17813
570-658-7491
<http://www.ricemachineryco.com>

SAR Biomass Energy Systems LLC
P.O. Box 203
Pocahontas IA, 50574
712-335-4616
www.sarcornfurnace.com

Smart Building Products
1658 Route 300
Newburgh, NY 12550
Ph:845-566-9329
<http://www.smartbuildingproducts.com>

Year-A-Round Corporation
110 West Lind Street
P.O. Box 2075
Mankato, MN 56002
800-418-9390
<http://www.year-a-round.com>

Carbon Diversion Flash Carbonization System USA, Commercial

Crop	Corn, garden and tree trimmings etc.
Residue	Corn cobs and stover, trimmings
Process	Flash Carbonization
Equipment	Transportable reactor system
Main Product	Carbon and electricity

Main Raw Materials Used: ³⁰

Green Waste

1. Urban tree Trimming
2. Household Garden Trimming
3. Landscape Trimming

Agricultural Waste

1. Corn cobs and corn stover
2. Manures

Logging and Mill Products

Food Processing Waste

Waste Hydrocarbons

Special Waste such as medical waste

Technical Description of Technology:

The system reactor converts waste materials into valuable products: carbon and electricity. A typical installation consists of two to four reactors, each capable of handling a one-ton load an hour. Two people staff this installation. One person loads and unloads the containers that fit into the reactor while the other person operates the reactor. A carbon diversion system requires ½ acre of land. This includes room to store materials to be processed, the reactor and its associated equipment, loading containers and bin to store carbon.

Detailed Process Descriptions:

To begin the Flash Carbonization process, biomass is loaded with a crane and packed into a vertical reactor chamber. The chamber is sealed and a flash fire is ignited at the base of the chamber. Heat released by the fire triggers the transformation of biomass into charcoal, sped up by a continuous flow of oxygen being pumped into the sealed reactor. Many organic materials as well as tires and biomedical waste can substitute wood and other forms of biomass.

Main Products: Charcoal Briquettes³¹

³⁰ <http://www.carbondiversion.com/>

³¹ <http://www.world-wire.com/news/0606190001.html>

The result is wood (biomass) can be converted into charcoal as quickly as 30 minutes, not 3 to 10 days, and has 200% more energy value than current commercial technologies.

Operation and Maintenance Requirements:

The reactor used in the Flash Carbonization process stands nine feet tall, three feet in diameter and requires only a ½ acre for operations. Unlike larger refineries, these reactors are easily transported, have lower capital requirements and are neighborhood friendly to serve small and rural communities. The reactors systems are simple to use, requiring a minimum of two on-site operators.

Social Considerations³²

The technology is an ideal solution as a renewable energy source in developing countries and is a needed recycling system for industrialized nations (green waste in the United States accounts for 1/3 of the waste stream and emits green house emissions when it decomposes).

Investments and Operating Cost³³

The University of Hawaii developed the technology in 2001 with money provided by the federal government, the University and the private sector. More than \$2 million was spent developing the patented technology, which also is licensed to Pacific Carbon and Graphite LLC and Waipahu-based Carbon Diversion Inc. Carbon Diversion, which has exclusive rights to manufacture charcoal using the UH process here in Hawai'i and other parts of the Pacific basin, said it recently landed its largest investment — \$2 million — which will be used to build eight charcoal production units in Kapolei.

Advantages to Developing Countries³⁴

Carbon Diversion, situated in Hawaii, is in an extremely strategic position to service partners in North America as well as Pacific Rim Countries including Asia, Australia and the smaller Countries of the Pacific Basin. The reactor and entire system have been designed to be portable and scalable – there is a mobile model for developing communities that is mounted on a truck and

driven around from one village to the next. As part of a dedication to bring the technology to the greatest number of markets, the company's strategy is to lease the technology to partners thereby reducing the upfront capital investment.

Examples of Real Life Applications

Campbell Industrial Park Kapolei, Oahu, Hawaii

³² <http://www.lohas.com/articles/81547.html>

³³ <http://the.honoluluadvertiser.com/article/2007/Jul/28/In/hawaii707280348.html>

³⁴ <http://www.world-wire.com/news/0606190001.html>

Suppliers:

Michael Lurvey, CEO
Carbon Diversion, Inc.
94-1031 B Maiiau Street
Waipahu, Hawai'i 96796
Phone/Fax: 808-671-1858
lurvey@carbondiversion.com
<http://www.carbondiversion.com>

Biomass Heating System³⁵ UK, Commercial

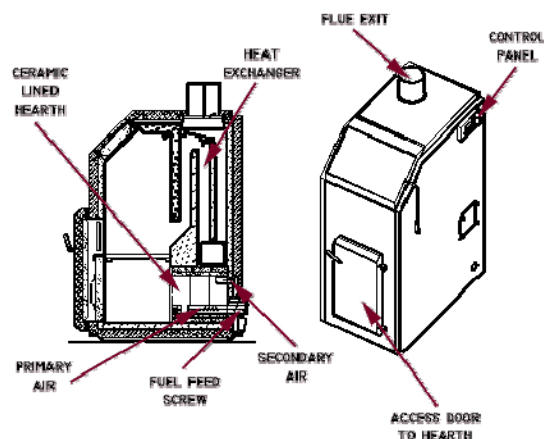
Crop	Wheat, oats and barley
Residue	Dry biomass waste
Process	Combustion
Equipment	Biomass Boilers
Main Product	Heat and steam

Production Capacity

High quality automatic wood-fuel boilers can operate between 20% and 100% of their maximum continuous rating (MCR) without a serious loss of efficiency. This enables a single boiler to be operated over a range of outputs and follow the heat demand more closely.

Detailed Process Description

Biomass heating systems are typically designed to replace either oil or gas fired boilers. Due to the nature of biomass fuels the boilers tend to be physically larger than those for oil or gas, they require more space and need to be located in a position that is easily accessible to fuel delivery vehicles. All automatic biomass-fired boiler plants are essentially similar, consisting of four key elements: Fuel storage, fuel feed mechanism, grate or hearth and heat exchanger.



Typical KSM Domestic Boiler Features

Operation and Maintenance Requirements

- Computer controlled for optimum efficiency and are easy to maintain and operate

³⁵ http://www.asgard-biomass.co.uk/biomass_heating.php

- Maintenance and operating procedures are similar to oil or gas boilers with the exception of some cleaning every one or two months

Wood combustion produces about 0.5 – 1.5% by weight of ash depending on fuel quality. This ash collects in an ash pan under the grate. It has to be removed manually in regular intervals depending upon heating demand. Automatic de-ash systems into a large ash bin (see Figure 7) reduce the amount of work required but the ashbin still requires removal and emptying periodically. This ash is safe for use as a soil fertilizer. It should be noted that all KSM boilers are fitted with automatic de-ash as standard. Boilers that incorporate cyclone separators trap minute particles passing through the boiler. Depending upon the operating conditions these separators will need cleaning every three to six months. For manually operated boilers the boilerplates and tubes will need to be scraped clean every six months to a year. Chimney flues will collect deposits of the tar and soot depending upon operating conditions. It is therefore advised that flues are checked annually and swept clean as necessary, which may be once a year or every two years. Motor and auger bearings need checking twice every year and greased according to the manufacturers specifications.

Environmental Considerations

- Subject to Pollution Prevention and Control Regulations 2000 (PPC)
- Installation uses the Best Available Techniques (BAT) in the design and operation of the plant to prevent pollution

Institutional and Regulatory Consideration or Requirements

- Subject to both the Waste Incineration Directive (WID) and the Pollution Prevention and Control Regulations 2000 (PPC)

The WID applies to all incineration and co-incineration plants. Co-incineration includes installations where waste is used as a fuel where energy generation is the main purpose.

All co-incinerators that fall within the WID are also subject to control under the PPC. Larger plant will be regulated by the Environment Agency under Part A (1) of Section 5.1 and smaller plant will be regulated by the local authority under Part A(2) of Section 5.1. Part A(2) applies to plant burning non-hazardous waste with a capacity of less than 1 Tonne per hour.

If a plant or 'installation' comes under the PPC Regulations then there must be an application made to operate such a facility.

Examples of Real Life Applications

Commercial use Biomass Heating System Unit 20, The Acorn Centre, Chestnut Ave., Biggleswade, Beds, SG18 0ra

Supplier

R.D. Associates, Ltd.

Fuel Delivery and Storage

Fuel is either supplied by an external contractor or as a self-supply operation, for example a farm or estate with its own wood harvesting operation. There are a number of mechanisms to deliver the fuel to the bunker. The simplest option is to tip the chips or pellets directly from a tipper truck or trailer into a subterranean bunker. Other options include dump bag systems, front-end loaders; purpose built containers, or pneumatic delivery. The options for fuel delivery and storage are mostly determined by the position of the boiler and the access to the premises being heated. The fuel delivery and storage system can account for a large proportion of the overall cost of installing biomass-heating systems. In new building applications, consideration to the location and operation of a biomass boiler and store should be undertaken as early as possible to avoid additional costs in the future.



Figure 2: Fuel Delivery
(tanker picture kindly supplied by [The Energy Crops Company Ltd.](http://www.energy-crops.com))

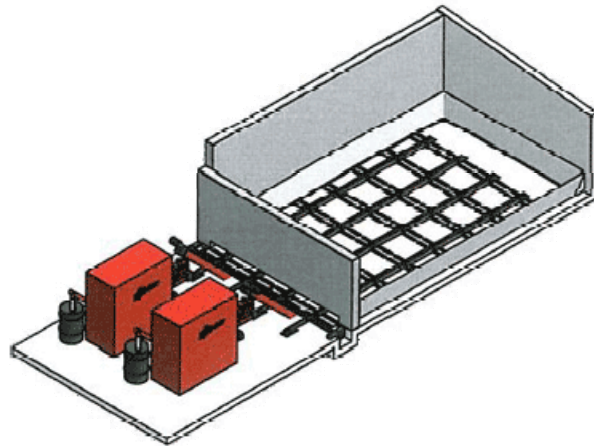
Fuel feed systems

Biomass fuels such as woodchip and oilseed cake are not free flowing materials and have a tendency to bridge, and so storage bunkers, or silos, are fitted with some type of agitator system. Small systems use rotating sweeper arm devices that drag the material over an auger as shown below.



Figure 3: Typical Sweeping Floor System

Larger woodchip storage systems require moving floors that move the material to an auger placed at the end of the bunker.



4: Typical Moving Floor System

Wood pellets flow very easily and do not need special agitator systems. The fuel is removed from the store by an auger, which lifts the fuel and deposits it in a drop cell, which has three key functions:

- It prevents air being drawn into the boiler
- It measures the woodchips being fed onto the boiler stoker conveyor
- It assists in preventing burn back from the boiler

The precise arrangements of the drop cell vary with individual suppliers. The KSM unit is shown in Figure 5.



Figure 5: KSM Drop Cell Unit

Some of the smaller, simple woodchip systems units may dispense with the drop cell and use a single short auger to feed fuel directly to the burner.

Grate (Hearth)

Comprises a short auger that feeds the fuel directly into the combustion zone. The type and design of the grate varies between individual manufactures. 'Underfed grates', as used in KSM boilers, are typically used with wood-fuels with moisture contents of 30% or less, 'Overfed grates' are used for small wood pellet burners and 'Moving step grates' are used for fuels with moisture contents of 30% to 60%.

Wood requires relatively little primary air (air supplied at the point of solids combustion, usually under the grate) but requires a good supply of secondary air (over-grate) to ensure that complete combustion takes place. All modern woodchip and wood pellet burners have provision for separate

control of the primary and secondary air supply, in order that combustion can be properly balanced. The combustion zone is usually insulated and comprises a primary and secondary chamber to ensure thorough mixing (turbulence) and time for the combustion reactions to occur.

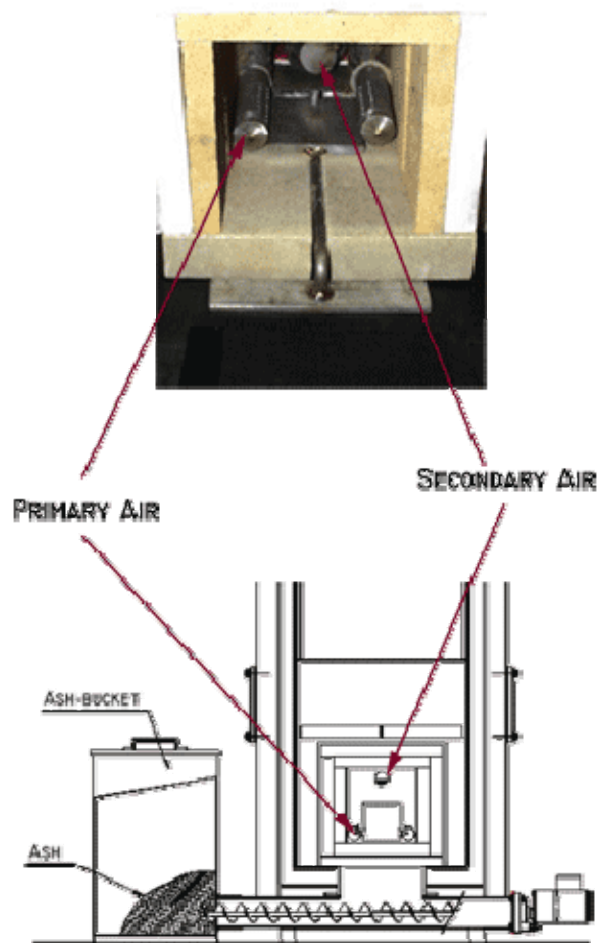


Figure 6: Typical KSM Hearth

Boilers are fitted with a number of control features. The inlet, outlet and room temperatures are monitored and linked to sensors that control the feed auger and determine the rate that fuel is supplied to the combustion zone. Sensors in the exhaust, monitoring oxygen and carbon monoxide levels (lambda sensors), are used to regulate the air supply and/or the fuel feed to maintain the correct air to fuel ratio for clean combustion and low emissions. In general wood fuel is a low sulphur fuel but has higher NO_x emissions than gas or oil boilers due to the inherent high nitrogen content of the fuel.

Heat Exchanger

These are conventional heat exchangers similar to those used for gas or oil fired boiler systems. They comprise either a simple water jacket or multi-pass fire tube positioned either horizontally or vertical. The boilers are highly efficient with typical efficiencies of 80% to over 90% for woodchip and wood pellet systems.

It should be noted that the KSM range of boilers have efficiencies of over 90%.

There is a tendency for fly ash to accumulate in the fire tubes, especially those set in a horizontal position, which then require cleaning at regular intervals dependent upon the fuel quality. A number of manufactures now offer automatic tube cleaning for larger boiler plant as a standard feature. This is recommended for ensuring high efficiencies and low maintenance costs. The larger systems are also fitted with cyclone separators to collect any fly ash passing through the boilers and into the environment.

Many boilers are also fitted with flue gas recirculation, which helps to control combustion temperatures and reduce NO_x formation.

Bio-oil from Forest Waste Canada, Commercial

Crop	Forest products
Residue	Forest waste
Process	Bio-refinery
Equipment	Transportable bio-refinery plant
Main Product	Heat and electricity
By-Product	Plastics and glues

Technical Description of Technology

To promote a more diverse and sustainable supply of electricity in the future, the Ontario government is building a bio-refinery to convert forest waste to bio-oil.

The transportable bio-refinery plant will convert unused forest waste into a bio-oil that can be used as fuel. The \$771,000 investment is part of ReNew Ontario, the McGuinty government's strategic five-year, \$30-billion infrastructure investment plan.

Under a three-year partnership with Advanced BioRefinery, the transportable bio-refinery plant will convert unused forest waste into a bio-oil that can be used as fuel to provide heat and electricity, and to make byproducts such as plastics and glues.

A sustainable supply of unused forest waste or biomass is available in Ontario's forests, such as tree tops, limbs and waste left after logging operations; trees destroyed by fire, insects and disease; and logs that can't be sold.

Investment Cost

\$771,000 investment

Example of Real Life Applications

Toronto, Ontario, Canada

Supplier

Advanced Biorefinery Inc
1391 Normandy cres. Ottawa, Ontario K2C 0N4
Peter Fransham, pfransham@advbiorefineryinc.ca

AgriPower³⁶
USA, Commercial

Crop	Mixed crops
Residue	Crop residue
Process	Combustion, "open" Brayton cycle
Equipment	Fluid bed combustor and several heat exchangers
Main Product	Electricity and heat
By-Product	Hot air

Technical Description of Technology

AgriPower is an energy conversion technology fueled with biomass to produce electricity and heat energy. The system operates with an "open" Brayton cycle using a fluid bed combustor and several heat exchangers to heat compressed air that in turn drives a turbine generator set.

Value-Added Product - Hot Air

The system discharges clean hot air that can be used for cogeneration. This supply of clean hot air (500 degree) is a value-added product that can be used for absorption chilling, ice making, food processing, etc. Also, the flue gas is available for fuel drying.

Modular and Transportable

The size and modularity adds economy to both the manufacturing process and the operation and maintenance. This project's concept of on-site energy production limits or eliminates the normal biomass risks and uncertainties regarding biomass feedstock price, quantity, timing of delivery, transportation, storage and handling costs.

³⁶ <http://www.agripowerinc.com/renewables.html>