Technical Assistance to Strengthen R&D for Climate Change Resilience of Agriculture in the Philippines

Reference: CPH1064

Preliminary review of technologies in operation in the Philippines to produce biomass energy and identification, related R&D centers, identification of one or two target regions for the study and of associated crops producing unused lignocellulosic biomass.
Final report - version 1.

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[1] Photo on cover: Multi-Fuel Biomass Furnace, PHilMech Design

Project summary

Project duration	**June 2023 to June 2024 – 1 year.**
Reporting period	March to April 2024
Global objective	Support to Philippines's agriculture and fisheries sector for Climate Change resilience.
Context	The Philippine government's R&D support for agriculture in general and R&D for climate-resilient have been minimal. In a context of a policy loan to the Government of Philippines for Climate Change, AFD is providing technical assistance to create a dialog for facilitating policy reforms which will enhance government's support for climate-resilient agriculture and fisheries sectors.
Specific objective	This Technical Assistance (TA) will provide technical support on R&D policy reforms and for climate-smart technologies and practices on high-value crops, fisheries, and livestock and poultry. CIRAD is engaged to provide R&D support to the Department of Agriculture (DA). The technical support will assist the Department of Agriculture of the Philippines in fulfilling its policy action and outcome commitments under Reform Area 2 (resilience to climate impacts enhanced) of the Subprogram 2 of the Philippine Climate Change Action Program (CCAP) co-financed by AFD and ADB.
Donor	Agence Française de développement
Beneficiary	Government of the Philippines, Department of Agriculture
Geographic scope	Philippines
Two main components	Component 1: Comprehensive policy review and appraisal of the agriculture R&D landscape in the Philippines. Two main deliverables: a main report and a policy brief. Component 2: Capacity building for Philippine agricultural research on specific themes: • 2.1 Genetic expert CRISPR/Cas9 -Training in France • 2.2 Mango data acquisition, analysis - (Pixfruit & Soyield). • 2.3 Research project on aquaculture • 2.4 Research on lignocellulosic wastes and by products • 2.5 Sugarcane technologies transfer and R&D
Scope of this report	Component 2.4: Research on ready-to-transfer existing technology and the use of by-products

1. INTRODUCTION

This review report provides a background of the potential lignocellulosic biomass resources of the Philippines, and highlights (1) a review of the different technologies in operation in the Philippines to produce biomass energy; (2) the different institutions and laboratories conducting R&D on biomass to energy and, (3) potential target regions in the Philippines where there is abundance of plant biomass waste that could be utilized for energy.

The Philippines is an archipelago in Southeast Asia that possesses abundant lignocellulosic biomass resources, which include agricultural residues, forest residues, and energy crops. Lignocellulosic biomass, primarily composed of cellulose, hemicellulose, and lignin, offers significant potential as a renewable and sustainable source for fuel, fertilizer, and energy production.

1.1. Agricultural residues

Agricultural residues in the Philippines represent a substantial portion of lignocellulosic biomass resources for valorization. These residues include rice straw, rice husk, sugarcane bagasse, corn stover and cobs, coconut shell and husks, and various other crop residues. Due to the country's significant agricultural activities, these residues are readily available and pose potential for bioenergy production and other applications.

The following table shows the main Philippine agricultural crops targeted by the study coconut, maize, rice and sugar cane - and the corresponding quantities of biomass produced.

Crop	Production (P) in the Philippines (in tons) [1]			H or Y*	Type of biomass	Average corresponding quantity of biomass by-product (B) theoretically produced (in tons)		
	2020	**2021**	**2022**			**2020**	**2021**	**2022**
Coconut	14 490 920	14 717 290	14 931 160	0,42	**shell and husks**	6 086 186	6 181 262	6 271 087
Maize	8 118 550	8 300 320	8 255 610	0,42	**stover and cobs**	11 211 331	11 462 347	11 400 604
Rice	19 294 860	19 960 170	19 756 390	0,44	**straw and husk**	24 557 095	25 403 853	25 144 496
Sugar cane	24 398 940	26 277 400	23 455 400	0,30	**bagasse**	7 319 682	7 883 220	7 036 620

* Average harvest index [2] (H) for maize and rice, or yield (Y) for sugar cane, coconut [3]

For maize and rice, B is obtained from P using the harvest index (H), which is the ratio between the marketable yield of the crop (grains for maize and rice) and the total quantity of biomass produced, expressed in dry weight (index between 0 and 1).

$H = P/(B+P)$ from which $B = P[(1/H) – 1]$

For coconut and sugar cane, the corresponding by-product production is equal to production P multiplied by the yield.

The table shows that for the 4 products, production has been relatively stable over the last 3 years.

Rice is the main source of biomass (straw and husk), followed by maize (stover and cobs), sugar cane (bagasse) and coconut (shell and husks).

Biomass production from the 4 main crops is therefore around 50 megatons, which is considerable.

1.2. Forest Residues

The Philippines is also endowed with diverse forest ecosystems, generating forest residues such as branches, leaves, and wood chips. Sustainable management of these residues can contribute to both environmental conservation and economic development through biomass utilization.

For wood production, ITTO and FAO statistics overlap and give equivalent annual production levels for the years 2020 to 2022: 4 million m3 of round wood and around 300,000 m3 of sawn wood.

For both round wood and sawn wood production, assuming a yield of between 30% and 50%, we can estimate the production of available biomass (by-product) from forestry production between 1.3 and 2.2 million m3, i.e. between 1 million and 1.5 million tonnes of by-product [4].

These quantities are not negligible but remain small compared with agricultural production.

This raises the question of the value of collecting this type of biomass resource, which is widely scattered compared with agricultural biomass.

Will it be necessary to take an interest given the relatively small quantities involved and, above all, the scattered nature of this resource?

The mission field trip and discussions with stakeholders will help to answer this question.

2. DIFFERENT TECHNOLOGIES IN THE PHILIPPINES FOR VALORIZING LIGNOCELLULOSIC BIOMASS TO ENERGY

Generally, the biomass to energy conversion pathways may either be through (1) thermal, (2) biological, or (3) chemical means. Most plant-based biomass in the Philippines are processed for heat or power through the thermal conversion pathway. These include direct combustion, gasification, and pyrolysis.

For biological processes, this is accomplished using naturally occurring microorganisms to convert biomass organic materials to various high energy liquid or gaseous fuels. Anaerobic digestion and ethanol fermentation are the most important processes for bioenergy production.

When the major component of biomass is oil, then the most logical biomass conversion pathway is to form esters of this oil through transesterification. One of the most popular biofuels from biomass is biodiesel, which is simply the ester of oil [5].

A large proportion of the plant residues that make up biomass cannot be used on their own to meet the energy needs. The inherent low-density property of biomass makes it difficult to handle, transport, store and burn. These problems can be overcome by densification, a process that produces a liquid or solid fuel that is denser and more uniform in properties than raw biomass. Such technologies are already available in the different institutions conducting R&D on plant-based waste to energy systems.

2.1. Some Thermal Conversion Technologies in the Philippines

2.1.1. Direct combustion

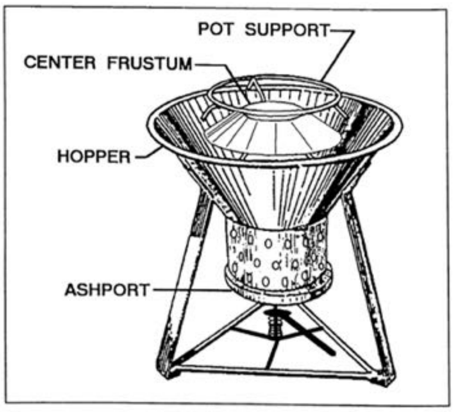
Direct Combustion is an age-old process of burning biomass for cooking or lighting. This is probably the most common way of utilizing biomass for energy, not just in the Philippines but in most developing countries. It is a common cooking practice in the countryside to use three stones in triangular formation to be used as pot supports while dry biomass from the surrounding area is burned underneath the pot. The preferred biomass fuels are dense, woody materials because of their higher calorific value.

Over the years a lot of furnaces and stove designs were developed with the objective of using a particular kind of biomass, improving cooking efficiency, or reducing health hazards from open direct combustion. Despite the availability of the different designs, based on the report of the Asian Development Bank (ADB), the Philippines still have the least access to clean cooking amongst the Southeast Asian countries [6].

Although biomass power plants are more complex than your simple biomass stove, these power plants still directly burn biomass to produce electricity. Biomass power plants operate similarly to traditional fossil fuel power plants in terms of electricity generation, but instead of burning coal or natural gas, they directly combust biomass as their primary fuel source. This reduces greenhouse gas emissions and utilizes renewable resources.

Stoves

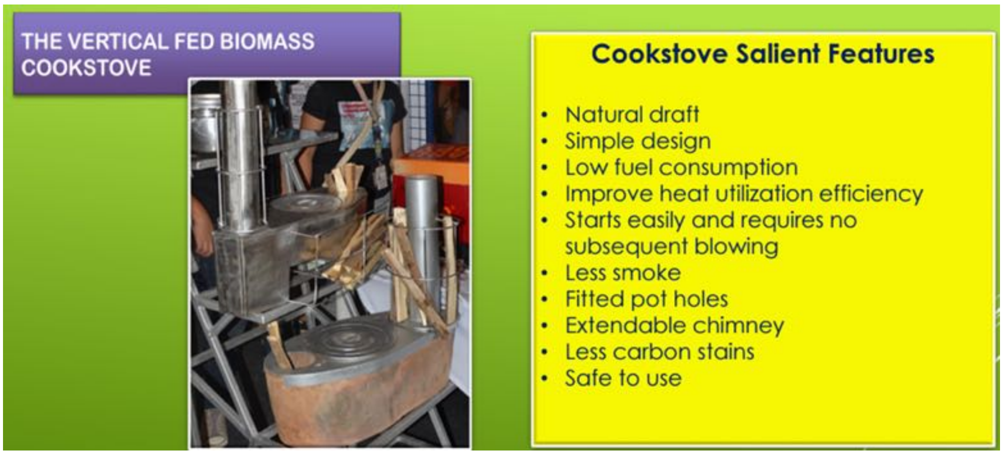
The following are some of those stove designs in the Philippines.



Early design of a Rice Hull-Biomass Cookstove [7].

Mabaga Kalan Wonder Kalan Papa brick stove

Improved cookstoves in the Philippines [6][8]



Vertical Fed Biomass Cookstove (Lacayanga, 2016) Bataan Peninsula State University [9]

Furnaces

According to the International Rice Research Institute (IRRI) [10], there are already various designs of rice husk furnaces, covering a wide range of designs, from the simplest where husk is piled on a grate to highly sophisticated types with conveyors and control devices. But because the simple designs are generally very labor intensive and the more complex designs require large investments and are prone to breakdown, rice hull furnaces were not widely used as heat sources for drying. However, since the turn of the century, which saw an increase in fossil fuel prices, they have become more popular, and several new designs have been developed since.

IRRI Designed Downdraft Rice Hull Furnace [11]

Multi-Fuel Biomass Furnace, PHilMech Design [12]

According to the developers, the multi-fuel biomass furnace optimizes the use of mechanical dryers because it uses rice hull and corn cobs as fuel.

The Specifications of the Multi-Fuel Biomass Furnace, PHilMech Design are as follows:

Power requirement	220 V 1.98 kW, single phase
Heating system	Indirect-fired
Heat exchanger material	Fire tubes
Burning chamber	Made of refractory bricks
Fuel feed	Auger type
Temperature control	Proportional Integral Derivative (PID) temperature controller that controls the feeding auger to maintain a set temperature
Fuel Corn	cobs or rice hull
Dimensions	Approximately 3 m x 1 m x 2 m (L x W x H) excluding chimney

Features

Made of high quality materials

Uses multiple kinds of biomass as fuel

Easy to operate and requires less labor attention

Provides clean hot air without smoke or ash entering the dryer

Environment friendly

With the proliferation of biomass furnace designs in the country, a means of evaluating the performance of these furnaces was realized. The Agricultural Machinery Testing and Evaluation Center (AMTEC) through the project "Development of Standards for Agricultural Production and Postharvest Machinery" funded by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development – Department of Science and Technology (PCARRD – DOST) formulated the Philippine Agricultural Engineering Standards PAES 242:2010, Agricultural machinery – Biomass Furnace – Specifications and Method of Test. [13] (AMTEC PNS 242:2010)

Biomass Power Plants

Based on the awarded Biomass Power Projects of the Department of Energy (DOE) [14], there are 33 Biomass Power Plant Projects that are currently operational with a combined Installed capacity of 579.651 MW

The following are three largest biomass power plants in Philippines located in Luzon, Visayas, and Mindanao. A brief description, the plant's location, capacity, and feedstock are also shown.

San Jose City - I - Power Corporation
Location: Luzon, San Jose City, Nueva Ecija,
Capacity: 24 MW
Feedstock: Rice Husk

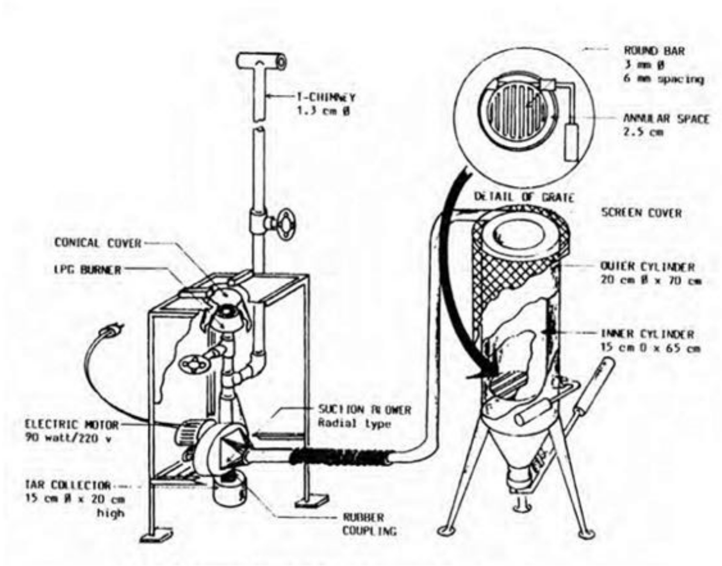
BISCOM, Inc.
Location: Visayas, Binalbagan, Negros Occidental
Capacity: 48.5 MW
Feedstock: Bagasse

Crystal Sugar Company, Inc.
Location: Mindanao, Maramag, Bukidnon
Capacity: 49.3 MW
Feedstock: Bagasse

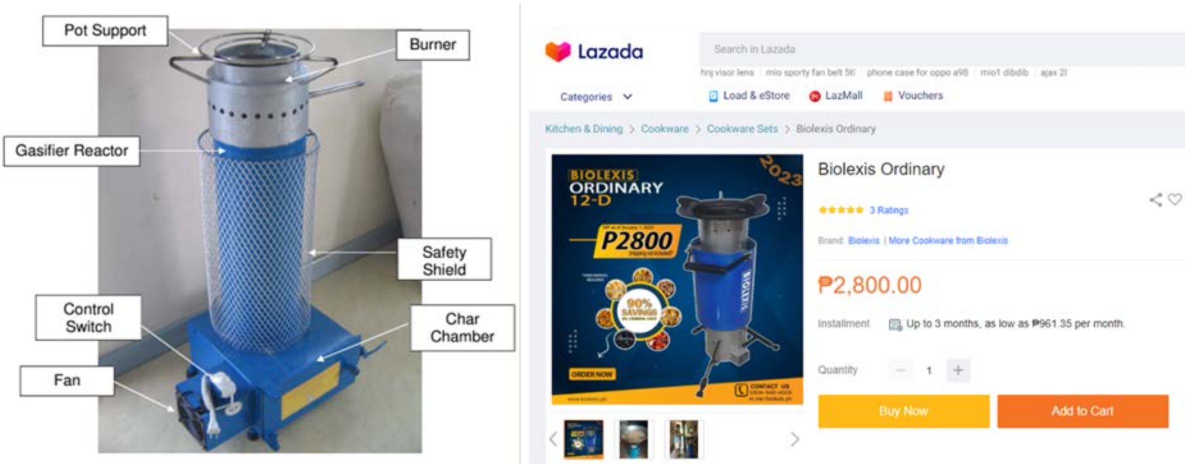
The three largest power plant in the Philippines make up about 21% of the total installed capacity for biomass power plants for the country.

2.1.2. Gasification

Gasification is a thermal conversion process that uses some amount of oxygen, but not enough for complete combustion. The process converts biomass into synthesis gas (syngas), which can be used for heat and power generation.



Drawing of the batch-type rice hull gasifier stove [15].



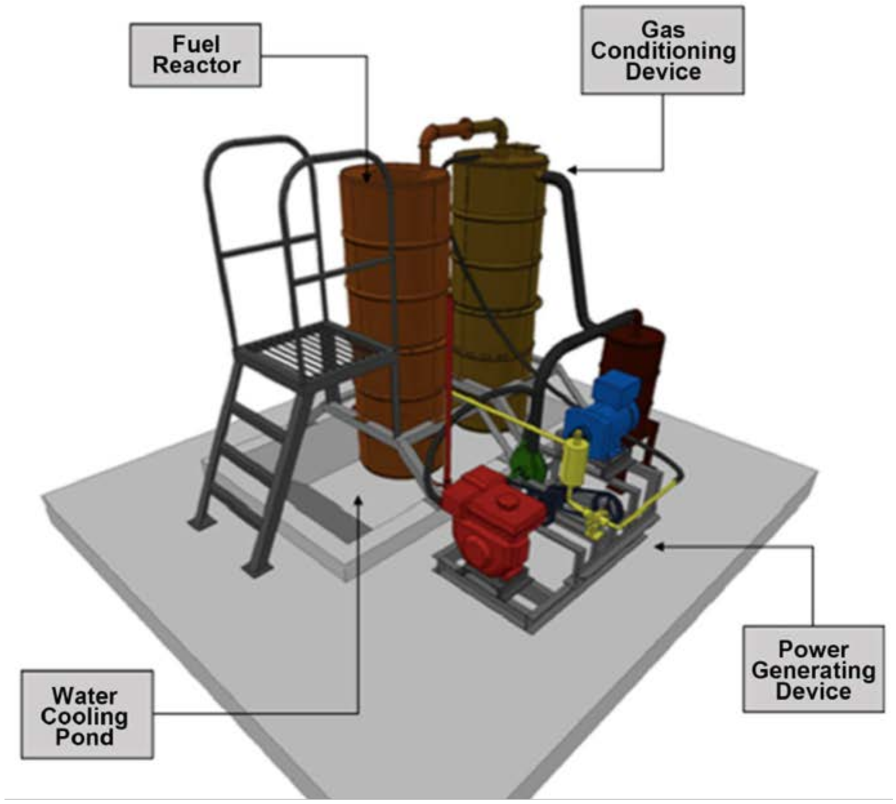
Modern Day Gasifier Stove Design available through online shopping [16], [17]

The Biolexis Multifuel Gasifier Stove is a portable stove which can operate using wood chunks, wood shavings, charcoal, coconut shell, corn cobs, nut shells, rice husk, among others. It was developed with the primary purpose of utilizing free and abundant “waste” resources for fuel to reduce or even completely eliminate expenses on fuel. It is said to be smokeless, and its waste product called “char” can be used as organic fertilizer for plants.

The following are the various Continuous Flow Rice Hull Gasifier (CFRHG) also designed by Dr. Alex Belonio.

The CFRHG Model-40D Used for Drying Paddy Seeds in Nueva Ecija, Philippines [18].

The CFRHG Model-100D Used for Baking Rubber in North Cotabato, Philippines [18].



The figures above are for the ARB Biomass Gasifier developed at PhilRice. It can drive stationary agricultural machines such as a 4-in. pump, a 30-cm biomass chipper, and a 20-cm rubber creeping mill. It can also power a 3-kWe AC generator for lighting and a 60-Amp DC alternator for charging batteries. [19]

2.1.3. Pyrolysis

Pyrolysis is the process that involves subjecting the biomass to elevated temperature under inert conditions to produce bio-oil, biochar, or activated carbon. It leads to the production of three constituents: a gaseous mixture consisting of non-condensable gas, bio-oil and a solid residue with a high carbon content called biochar. Biochar is a charcoal that can be produced either in a traditional way or industrially.

The development of biochar manufacturing techniques and the use of this biological fertiliser has expanded considerably in recent years.

What is biochar?

The term 'biochar' is an abbreviation of 'bio-charcoal', from the prefix 'bio' meaning biological origin and the word "charcoal". It refers to charcoal of vegetable origin obtained by pyrolysis of biomass of organic matter of various origins.

Conventionally (*International Biochar Initiative*), the term biochar refers to any carbonised organic material that has been carbonised for the purpose of soil application or carbon sequestration.

Biochar is a solid that is rich in stable carbon and recalcitrant to mineralisation by soil micro-organisms, due to its composition, which is rich in aromatic structures. It thus plays the role of carbon fixation in the soil and therefore of carbon sink, which explains its interest in the context of concerns about global warming.

Biochar can be produced from organic matter of various origins (agricultural residues, manure, forestry residues, etc.).

The benefits of biochar

- Improves soil pH at low cost
- Increases the retention capacity of mineral elements and the availability of phosphorus in the soil.
- Stimulates soil microbial life
- Improves porosity and helps purify soil and water

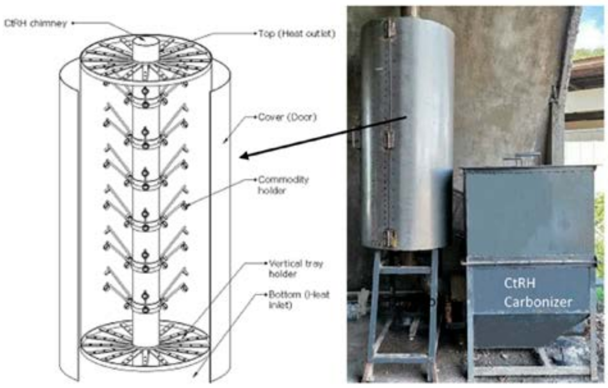
Application of biochar

Several factors in the pyrolysis process influence the quality of the biochar obtained, hence the importance of characterising the biochar before it is applied to the soil and the environment. It is also important that experiments are carried out in controlled environments and in the field before determining the dose of biochar to apply to a given type of soil or crop. In general, the poorer the soil, the greater the effect of biochar on the soil.

Light-textured, sandy or sandy soils are better suited to biochar applications than heavy-textured soils such as clay.

The figures below show the Continuous type Rice Hull (CtRH) Carbonizer with different attachments (Figures a, b, c, d). It was designed for cogeneration of biochar and heat. This was developed by Dr. Ricardo Orge of PhilRice [20, 21, 22].

(a) Carbonizer with cooking attachment

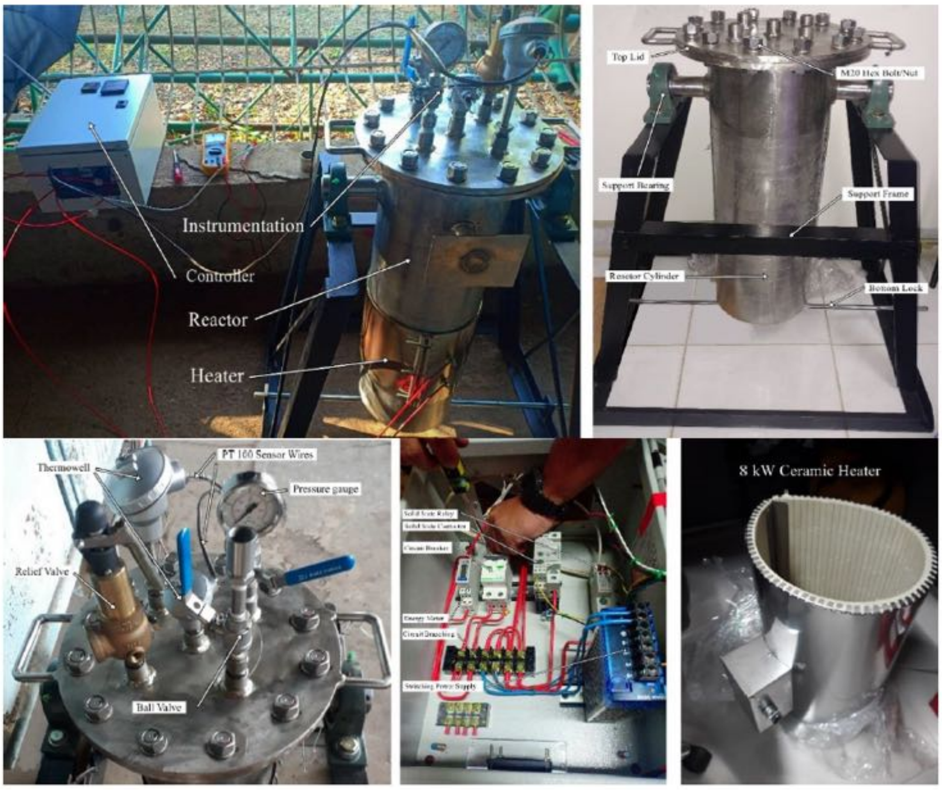


(b) Carbonizer with drying oven attachment (c) Carbonizer attached to a poultry house

(d) Carbonizer with oven attachment for roasting chicken

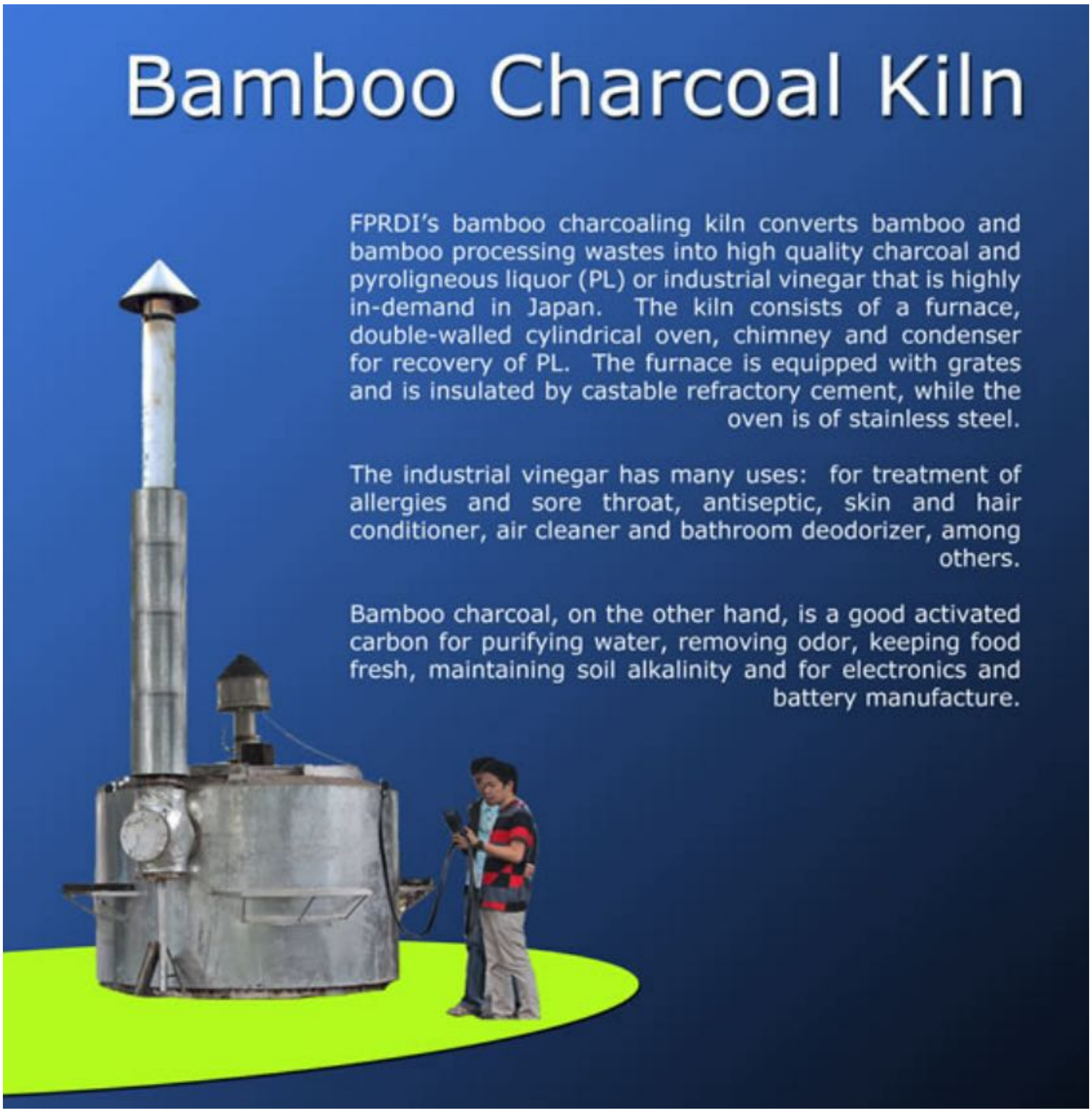
Hydrothermal carbonization (HTC) is a thermochemical treatment process especially designed for wet feedstock to produce solid coal-like product named hydrochar. Products of the process include solid char yield, liquor containing carboxylic acids, furan derivatives, phenolic substances, and sugar monomers, and CO2 rich gaseous product. Moreover, initial studies show HTC improved the fuel values of the char and are considered CO2 – neutral bio-coal and bio-char. HTC hydrochar can be used not only for various applications in the bioenergy value chain, but also in agriculture and gardening as renewable peat but its main application is as solid biofuel.

The Department of Agriculture (DA), Philippine Center for Postharvest Development and Mechanization (PHilMech) and the Department of Agricultural and Biosystems Engineering, Central Luzon State University (CLSU) co-developed a Hydrochar Production system for processing wet biomass via HTC [23].

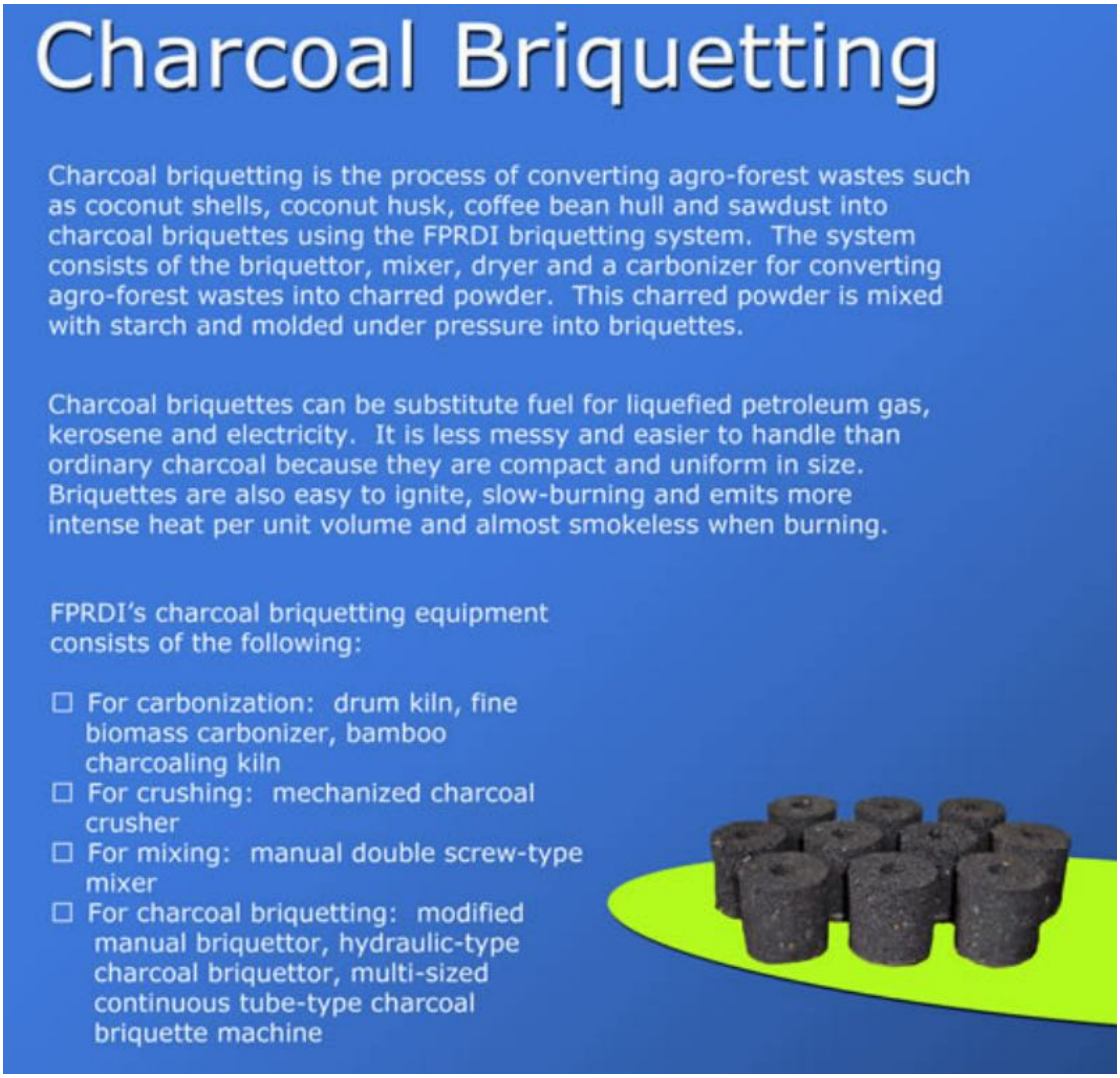


Hydrothermal Carbonization Reactor

The Department of Science and Technology (DOST) -Forest Products Research and Development Institute (FPRDI) developed a Bamboo Charcoal Kiln for pyrolyzing bamboo processing waste [24].



The DOST-FPRDI also developed a charcoal briquetting system for various agro-forest wastes. The system makes use of carbonizer, crusher, and briquetting machines [ ].



Note: The biochar production situation in the Philippines will be described as part of the study, and the development prospects for this type of use will be analysed in view of its interest, given its dual impact on the use of lignocellulosic biomass and on the development of a more environmentally friendly form of agriculture.

Similarly, the Philippine Coconut Authority (PCA), Zamboanga Research Center (ZRC), also developed a Briquetting System for coconut biomass. The system utilizes a brick charcoal kiln, grinding machine, mixer and briquetting machine that could be either mechanically or manually operated [25].

Coconut Charcoal Briquetting System Developed by the PCA-ZRC

2.2. Some Biological Conversion Technologies in the Philippines

2.2.1. *Anaerobic Digestion*

Anaerobic digestion of lignocellulosic biomass presents some challenges due to its complex structure and resistance to degradation compared to simpler organic materials like animal manure or food waste.

To effectively utilize lignocellulosic biomass for biogas production, pretreatment methods are often employed to break down the tough structure and enhance the accessibility of the organic matter to microbial digestion.

This is probably the main reason why biogas production technology for the Philippines is limited to digestion of mostly biomass from animal waste.

Biogas technology was first introduced in the Philippines in 1965. However, technology received little social or economic support at the time. Biogas plants were not yet economically feasible as abundant and cheap coal was primarily used to generate power. In the following decades, practical biogas applications were limited to biogas digesters for home use. Today, there are several industrial-scale biogas plants in the Philippines that generate energy from organic waste. Despite this development biogas production still plays a rather small role as a renewable energy source. Biogas has accounted for less than 1% of the power generation mix in 2020 [26].

The Department of Science and Technology (DOST) has been promoting biogas technologies throughout the Philippines for more than 20 years, mainly focusing on dome type digesters that can convert wastes from piggeries and poultry farms. In addition, the Environmental and Biotechnology Division of Industrial Technology Development Institute (ITDI) of DOST has been promoting portable digesters to produce biogas from the kitchen or food waste. This aims to promote the conversion of biodegradable waste from the Materials Recovery Facility of several barangays in Metro Manila.

For household and small farm applications, various biogas bag digesters are already in the Philippine market. Most of these are imported from China [27].

Because the principle of AD is very simple and a lot of 'Do-It-Yourself' (DIY) information is available on the internet, there are now many hobbyists, enthusiasts and even large-scale producers of biogas in the Philippines.

Again however, the favored feedstock is mostly using animal and biodegradable industrial wastes.

Philippine BioDigester, Home Biogas System (HBS) [28]

A Small-scale Biodigester Designed and Built in the Philippines [29]

Novel Low-Cost Plastic Drum Biogas Digester designed by Dr. Antonio J. Barroga of CLSU [30]

IRRI Batch Biogas or Anaerobic Digester [31]

Floating Drum Digester at the Pampanga Agricultural College [32]

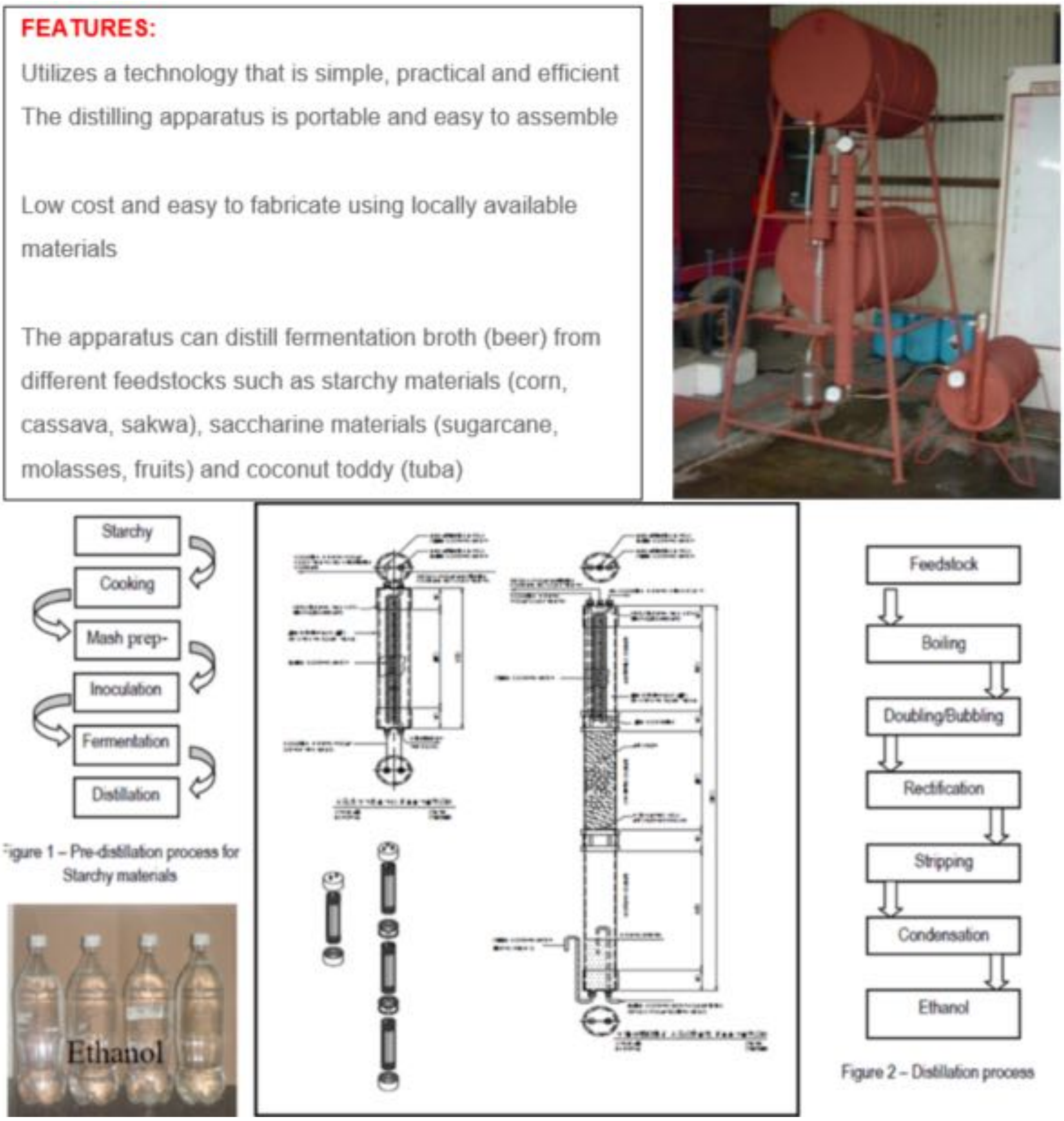
In the Philippines, based on the list of awarded Biomass Power Projects of the Department of Energy, there are 5 major biogas power plants with a combined capacity of 18.99 MW. These are as follows:

1)	Asian Carbon Neutral Power Corporation	3.0MW
2)	Far East Alcohol Corporation	2.4MW
3)	First Quezon Biogas Corporation	1.2MW
4)	Biotech Farms, Inc.	12.39MW
5)	Surallah Biogas Ventures Corporation	3.068MW

2.2.2. *Ethanol Production*

The Center for Agri-Fisheries and Biosystems Mechanization (BIOMECH) formerly known as the Agricultural Mechanization Development Program, developed a Village level Ethanol Production System.

This technology can provide the rural communities with an accessible and dependable source of energy and fuel. Ethanol can be used as fuel to slightly modified gasoline engines which when coupled to generator would provide electricity for lighting. It could also be readily fueled into modified engines to serve as power source for power tillers, irrigation pumps, threshers and other agricultural machines and implements needing power [33].



UPLB-BIOMECH Village level Ethanol Production System

Similarly, the Mariano Marcos State University and the Central Luzon State University have their own village level ethanol production design for producing hydrous bioethanol for fuel blending.

Modern distillation facility at the National Bioenergy Research and Innovation Center (NBERIC), Mariano Marcos State University [34].

2.3. Biodiesel Production Plants

Biodiesel production plants mostly use the chemical conversion pathway due to the higher production system efficiency from such plants. According to the DOE, there are 11 Biodiesel production plant all throughout the Philippines, with a combined capacity of 617.9 million liters/year. These are located in Luzon and Mindanao [35].

The following are pictures from the largest producer of coconut methyl esters (CME) or coco biodiesel in the Philippines. The Tantuco Enterprises Inc. [36].

CME Production

Methanol Recovery

TSD – Laboratory

3. SOME INSTITUTIONS IN THE PHILIPPINES ENGAGED IN BIOMASS RD&E

Laboratories and research centers for potential collaboration with CIRAD would logically be coming from (1) Academic institutions, (2) Government Agencies, (3) Non-Government Agencies (4) Industry Partners. Also, (5) farmers and farmer's organizations can be an important source of information since they are most probably the major stakeholders.

3.1. Academic Institutions

3.1.1. The University of the Philippines Los Baños (UPLB)

A coeducational publicly funded academic, research and extension institution, is one of the eight constituent universities of the University of the Philippines System. UPLB is an emerging international leader in higher education and a highly ranked university in the Philippines that has advanced innovation, knowledge generation, and public service to pursue the goals of social transformation and sustainable development in the country [37].

By virtue of a presidential decree, various research units of UPLB were recognized as centers of excellence namely:

- Institute of Plant Breeding
- Institute of Food Science and Technology
- Institute of Animal Science
- National Crop Protection Center
- Farming Systems and Soil Resources Institute
- National Institute of Molecular Biology and Biotechnology

Inside the UPLB campus, it hosts different government, non-government and international institutions (e.g International Rice Research Institute (IRRI), The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), ASEAN Center for Biodiversity, The Philippine Rice Research Institute (PhilRice), The Forest Products Research and Development Institute (FPRDI), The Ecosystems Research and Development Bureau (ERDB)).

*** UPLB, National Institute of Molecular Biology and Biotechnology (BIOTECH)**

Biotechnology for Industry, Environment, and Energy Program (BIEEP) aims to address environmental problems and mitigate effects of climate change by developing technologies and sustainable strategies. Its efforts include production of bioethanol and biodiesel from renewable resources; use of microorganisms for the degradation of plastics; plastic-related compounds and plastic containing packaging materials; microbial degradation of oily/lipid-containing agro-industrial wastes; production of biomass and biomolecules (biosurfactants, enzymes) from yeasts for industrial and environmental applications; and development of microbial-based technologies for agro-industrial waste management. The program also provides technical assistance to the industry for environmental management [38].

*** UPLB, Center for Agri-Fisheries and Biosystems Mechanization (BIOMECH)**: Formerly known as the

Agricultural Mechanization Development Program (AMDP), with its numerous achievements and crucial role not only in the University but in the National level as well, it was elevated to the Center for Agri-Fisheries and Biosystems Mechanization (BIOMECH) in 2015 to effectively pursue its mandate in alleviating the plight of our marginalized sector by continuously doing innovative agricultural and biosystems engineering interventions. Together with the faculty of College of Engineering and Agro-industrial Technology, it has co-developed numerous agricultural technology systems including the development of a village level bioethanol production system [39].

*** UPLB, Institute of Agricultural and Biosystems Engineering (IABE)**- The Agribiosystems Machinery and Power Engineering Division (AMPED) is one of the academic units of the Institute of Agricultural and Biosystems Engineering. AMPED was created to provide leadership in the field of agricultural machinery, agricultural energy and power systems, and mechanization. The division spearheads instruction, research, and extension of renewable energy technology on biomass, solar energy, micro hydropower, and wind energy [40].

*** UPLB, The Department of Chemical Engineering (DChE),** Biomass and Energy Research Laboratory - houses the Biomass and Energy Research Laboratory, focused on interdisciplinary research in biomass utilization. The laboratory investigates various aspects of biomass valorization, including pretreatment methods, enzymatic hydrolysis, and biorefinery processes. DChE also hosts the UPLB Interdisciplinary Life Cycle Assessment Laboratory (UPLB ILCAL) [41].

3.1.2.Central Luzon State University (CLSU)

By virtue of Republic Act No. 4067 dated June 18, 1964, the Central Luzon Agricultural College (CLAC), located in Muñoz, Nueva Ecija, Philippines, was converted into the Central Luzon State University (CLSU) thereby providing professional and technical training in agriculture and mechanic arts besides providing advanced instruction and promoting research in literature, philosophy, the sciences, technology and arts.

CLSU has significantly contributed to agricultural development in the Philippines through its research and development (R&D) initiatives.

CLSU's agricultural research programs focus on enhancing crop productivity, improving farming practices, and promoting sustainable agricultural systems, thereby addressing food security challenges and improving the livelihoods of farmers. Additionally, CLSU has been actively involved in R&D work on renewable energy, particularly in the utilization of agricultural biomass for bioenergy production. Through innovative projects and partnerships, CLSU has advanced technologies for converting agricultural residues into biofuels, biogas, and other forms of renewable energy, contributing to energy security, environmental sustainability, and rural development in the Philippines. [42].

3.1.3.Mariano Marcos State University (MMSU)

The National Bioenergy Research and Innovation Center (NBERIC) The National Bioenergy Research and Innovation Center (NBERIC) at Mariano Marcos State University (MMSU) has played a pivotal role in advancing research and development efforts in the field of biomass energy. Through cutting-edge research initiatives and collaborative partnerships, NBERIC has focused on developing sustainable technologies for converting biomass waste, such as rice straw and husks, into biofuels, biogas, and other forms of renewable energy. By pioneering innovative solutions and promoting knowledge transfer, NBERIC has not only contributed to reducing greenhouse gas emissions and mitigating climate change but has also facilitated the adoption of bioenergy technologies to enhance energy security and promote socio-economic development in the Philippines. [43]

3.1.4. Benguet State University (BSU)

Part of the mandate of BSU is to promote research, extension, agribusiness, and advanced studies and progressive leadership in its field of specialization whereby organized relevant research centers in the University have been established to develop technologies on sub-tropical agriculture and natural resources, which will backstop and enhance the growth and development of the Cordillera area and other highland areas [44].

3.2. Government Agencies

3.2.1. Department of Agriculture - Philippine Center for Postharvest Development and Mechanization (DA-PhilMech)

DA-PhilMech is mandated to enhance agricultural productivity and postharvest technologies in the Philippines. The center conducts research on agricultural residues management, including the development of mechanized systems for biomass collection, processing, and utilization in bioenergy production [45].

3.2.2. The Department of Agriculture - Philippine Rice Research Institute (DA-PhilRice)

DA-PhilRice is a government research institute, Department of Agriculture, dedicated to advancing rice science and technology in the Philippines. The institute has developed Biochar-based technologies for enhanced productivity, efficiency, resilience and adaptive capacity for smallholder rice-based farming communities in the Philippines [46].

3.2.3. Department of Science and Technology - Forest Products Research and Development Institute (DOST-FPRDI)

DOST-FPRDI is mandated to generate, improve and transfer appropriate technologies and information on efficient utilization of forest-based products to make local industries more competitive in the domestic and global markets and to benefit the general public. The institute has conducted various research on forest residues and wood waste, developing technologies for biomass valorization [47].

3.2.4. The Department of Agriculture - Philippine Coconut Authority (DA-PCA)

DA-PCA is responsible for promoting the development off the coconut industry in the Philippines. The authority conducts research on coconut husk and shell utilization, exploring opportunities for converting coconut biomass into biochar, activated carbon, and bio-based fertilizers [48].

3.2.5. Department of Science and Technology - Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD)

DOST-PCIERD plays a significant role in advancing research and development efforts related to utilizing rice biomass waste in the Philippines. Through funding support, collaborative partnerships, and technology transfer initiatives, DOST-PCIERD facilitates the development and adoption of innovative technologies for converting rice straw and husks into value-added products, bioenergy, and bio-based materials. By promoting sustainable utilization of rice biomass waste, DOST-PCIERD contributes to enhancing agricultural productivity, addressing environmental challenges, and fostering economic growth in the Philippines. [49].

3.2.6. Local Government Units

Based on the Local Government Code of the Philippines which took effect on January 1, 1992, the municipal and city Local Government Units (LGUs) shall discharge the functions of national agencies and offices thereby providing extension and on-site research services and facilities related to agriculture and fishery activities [50].

LGUs in the Philippines can play a crucial role in extending technologies for biomass waste valorization, particularly in rural areas where rice farming is prevalent. LGUs can facilitate the dissemination of information and knowledge about available technologies for converting rice biomass waste into valuable products, bioenergy, and fertilizers.

By establishing partnerships with research institutions, industry stakeholders, and community organizations, LGUs can promote the adoption of sustainable agricultural practices and provide support for the implementation of biomass valorization projects.

Additionally, LGUs can incentivize farmers and cooperatives to participate in biomass waste management initiatives through policy support, capacity building programs, and financial assistance schemes.

Through proactive engagement and collaboration, LGUs can contribute to the development of a circular economy approach to rice farming, addressing environmental concerns, enhancing rural livelihoods, and promoting economic development.

3.3. Non-Government Agencies

3.3.1. International Rice Research Institute (IRRI)

IRRI is actively engaged in research and development efforts to utilize rice biomass waste effectively.

Their work focuses on converting rice straw and husks into bioenergy, recycling nutrients back into agricultural systems, mitigating climate change by reducing straw burning, and creating value-added products like bioplastics and biochar. Through partnerships and capacity-building initiatives, IRRI aims to promote sustainable agricultural practices, enhance livelihoods, and contribute to global efforts for a more sustainable future. [51].

3.3.2. The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA)

This Center has been instrumental in promoting agricultural development in the Philippines and the Southeast Asian region. Through its research, training, and knowledge-sharing activities, SEARCA has contributed to enhancing agricultural productivity, improving food security, and fostering sustainable rural development. By facilitating collaboration among policymakers, researchers, educators, and farmers, SEARCA has played a key role in addressing pressing agricultural challenges, promoting innovation, and empowering communities to build resilient and inclusive agricultural systems that benefit both present and future generations in Southeast Asia.

3.4. Other Institutions

There are so many institutions that are stakeholders in the wide field of biomass waste to energy. Due to proximity of these two institutions to UPLB. A short trip would be made to their facility. Straw Innovations Ltd.at Pila Laguna, and Los Baños Folia Tropica.

4. REGIONS IN THE PHILIPPINES WHERE THERE IS ABUNDANCE OF PLANT BIOMASS WASTE

The Philippines possesses a total land area of 30 million hectares, with 32% designated as agricultural land. Among this agricultural expanse, 9.67 million hectares are allocated to the cultivation of both food and non-food crops and grains. Key crops cultivated include palay or rice, corn, coconut, and sugarcane. These crops not only serve as essential food sources but also significantly contribute to the country's bioenergy resources. Despite their value, agricultural residues such as rice straw, corn cobs, and coconut husks are often disregarded as waste, left to accumulate in fields post-harvest. However, these residues, including rice hulls, sugarcane bagasse, corn stover, and coconut shells, can be reclaimed for various purposes following processing.

In 2015, a study was conducted to establish the potential of bioenergy production from three major agricultural residues in the Philippines (rice, corn, coconut) [54]. Sugarcane was not included because the study revealed that sugarcane bagasse was used for cogeneration after milling.

It was established that the top rice producing provinces include: Nueva Ecija, Pangasinan, Isabela, Iloilo, Cagayan, Camarines Sur, Tarlac, Leyte, North Cotabato and Maguindanao.

The highest corn producing provinces include Isabela, Bukidnon, Maguindanao, South Cotabato, North Cotabato, Ilocos Norte, Lanao del Sur, Cagayan, Lanao del Norte and Pangasinan

The highest coconut producing provinces include Quezon, Davao Oriental, Davao del Sur, Zamboanga del Norte, Leyte, Lanao del Norte, Zamboanga del Sur, Misamis Occidental, Misamis Oriental, and Maguindanao.

Due to the short time for the mission, Target regions to visit would be South and Cental Luzon only, targeting Laguna, Quezon, and Nueva Ecija.

As part of the study, it will be necessary to estimate how much of this biomass has already been used locally, regionally or nationally, and how much is currently unused (burnt or abandoned) and could be used for energy production.

It is highly likely that a significant proportion of this biomass is already being used effectively, particularly by local populations.

These current recovery methods must not be disrupted in any way by the introduction of new recovery routes for energy production.

5. CONCLUSION

Lignocellulosic biomass presents significant opportunities for sustainable fuel, fertilizer, and energy production in the Philippines.

By leveraging valorization principles and advancing biomass research and development, the country can harness its abundant biomass resources to achieve energy security, environmental sustainability, and rural livelihood enhancement.

Lignocellulosic biomass holds immense potential for sustainable energy production and resource utilization in the Philippines. This review revealed that there are numerous institutions in the Philippines that are doing RD&E on processing plant biomass waste into energy and other useful forms. Also, the review established that, there are already various technologies available to accomplish the conversion. Furthermore, the provinces where there is a most likely abundance of plant waste biomass in the country have been identified.

Moving forward, the pertinent information from this review will be considered carefully. The objective of strand 2.4 Research on ready-to-transfer existing technology and the use of by-products of this Technical Assistance to strengthen R&D for more climate-resilient agriculture in the Philippines will therefore be specifically focused on studying the feasibility of setting up one or more biomass recovery units.

These units will have a multifunctional vocation, meaning that they will have to integrate the production of different forms of biomass energy, considering the sources and methods of supply, the associated constraints and the associated markets at local, regional, national and international level.

The technologies to be implemented will have to be described, even if they are perfectly known and mastered today, and therefore applicable to the Philippines.

The choice of technologies will be based on an analysis of the biomass resources available in the country, their accessibility and mobilisation potential, as well as existing know-how at national level.

As mentioned above, it will be particularly important to be vigilant about existing ways of using lignocellulosic biomass in the country.

These recovery methods, whether formal or informal, generate income for people in the production regions. The conversion units to be set up must not in any way disrupt these existing sectors, by upsetting the often-fragile balances sometimes linked to the low profitability of these sectors, which nevertheless provide a living for many people.

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