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

Reference: CPH1064

Assessment of the existing R&D capacities for the development of biomass energy, of the associated technical, scientific and financial needs, and corresponding recommendations

****

R&D specifications for a technology transfer project for biomass industry

****

FINAL REPORT

Dr. Jean Gérard, CIRAD - BioWooEB, France
Dr. Patrick Langbour, CIRAD - BioWooEB, France
Dr. Fernando Paras Jr., UPLB - IABE, Philippines

June 14, 2024

CIRAD : Centre de coopération Internationale en Recherche Agronomique pour le Développement
Campus international de Baillarguet TA 10/B, 34398 Montpellier cedex 5, France

Table of contents[1]

[1] Photo on cover, from left to right: Fernando Paras Jr. (UPLB - IABE, Philippines), Thierry Liabastre (AFD, France), Jean Gérard (CIRAD - BioWooEB, France), Patrick Langbour (CIRAD - BioWooEB, France)

Project summary

Project duration	**June 2023 to June 2024 – 1 year.**
Reporting period	March to May 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. Background

This report is the result of the mission to the Philippines from 21 to 29 March 2024, which was the subject of the report entitled *Assessment of the existing R&D capacities for the development of biomass energy, of the associated technical, scientific and financial needs, and corresponding recommendations - Interim report - final mission report* (23 April 2024).

This mission fell within the scope of amendment n°1 to the service contract *Technical Assistance to Strengthen R&D for Climate Change Resilience of Agriculture in the Philippines* (reference: CPH1064).

More specifically, it concerned Component 2: *Capacity building for Philippine agricultural research on specific themes*, phase 2.4. *Research on ready-to-transfer existing technology and the use of by-products*.

This mission validated and adjusted the elements of the review of technologies in operation in the Philippines to produce biomass energy and identification, and related R&D centres. These elements were already provided in report *2.4.1 Preliminary review*.

The main objective of the mission was the *Assessment of the existing R&D capacities for the development of biomass energy, of the associated technical, scientific and financial needs, and corresponding recommendations*.

The aim of this mission was to define ***Specifications for a feasibility study for the implementation of one (or more) biomass energy production unit(s) by thermochemical conversion of lignocellulosic biomass consisting of related products and by-products of the agricultural and forestry sectors, for the production of biofuels***.

These specifications form the core of this report.

2. Main conclusions of the mission to the Philippines

* Rice by-products are logically the most abundant agricultural biomass resources in the Philippines, given the importance of rice production in the country (30% of Philippine land is devoted to rice cultivation, with an average per capita consumption of 123 kilos per year), and the fact that the country is not self-sufficient in this strategic commodity (in 2023, the Philippines imported over 3.5 million tonnes of rice, with a forecast of 4 million tonnes in 2024).

Visits and discussions during the mission highlighted the need to valorise rice by-products, straw and husks.

The use of rice husks appeared to be the least problematic due to the concentration of this biomass at production collection points, thus limiting logistical obstacles.

The rice husk biochar production unit (ALCOM) demonstrates this fact, and reveals the development prospects for this type of valorisation.

This is one of the value-addition options to be proposed in phase 2.4.3 of the project.

* On the other hand, the valorisation of rice straw has proved much more problematic, due to the dispersed nature of the resource and the complexity of collection and mobilization.

Traditionally, this biomass was burned on site, contributing to soil improvement.

Today, burning is theoretically prohibited.

Rice straw is left on site, contributing to soil fertilization, but with a fairly slow degradation, due in particular to decomposition partly under water in an anaerobic phase.

It is also used as a raw material, often braided, to make small objects such as those on display at IRRI (baskets, containers, household utensils). This type of recycling remains very marginal.

Because of its dispersed nature and the current lack of satisfactory valorisation, the direct production (heat production) of decentralized energy using simple devices such as those developed by the FPRDI, carbonizer, drum kiln, charcoal kiln, or indirectly (production of briquettes or pellets) using simple devices such as Briquettor or Pellets device will be another proposed way of valorisation (collaboration with UPLB and CLSU).

* The mission revealed that another category of by-products is currently under-utilized: wet to very wet waste. This includes vegetable production waste, such as that from the Benguet Agri-Pinoy Trading Centre in Baguio.

At this collection centre, composting could be a suitable solution, but is not implemented due to lack of space and the nuisance associated with the degradation of organic matter (odour problems): on the Baguio plain, all available land is devoted to crops, so composting requires large areas.

For this type of wet waste, two types of technology can be considered:

1. Hydrochar production systems such as those developed by PhilMech appear to be suitable.
2. Methanisation in a digester in the absence of oxygen and in the presence of bacteria to produce biogas.

The next stage of the project will propose a double way of using wet waste to produce: (1) hydrochar, in particular from vegetable production waste, but also for corn by-products with a high moisture content; (2) biogas from these vegetable wastes using methanisation technique.

* Biomass Energy Resources Atlas of the Philippines update

This Atlas was produced by the Institute of Agricultural and Biosystems Engineering (IABE) in the 2000s with American funding (National Renewable Energy Laboratory - NREL; USAID).

During discussions with IABE representatives, it was unanimously agreed by all stakeholders that it would be highly opportune and profitable to update this Atlas, which is an essential prerequisite for the actions to be undertaken to develop the use of biomass of agricultural origin for energy production. **Updating this Atlas will be one of the actions proposed for phase 2.4.3 of the project.**

Note: two other by-products of agricultural production were not discussed: sugarcane bagasse, coconut shells; according to the information obtained during the mission, both of these by-products are currently fully valorised for all or part of the energy used in sugarcane and copra production and processing units respectively.

Consequently, 4 projects are proposed in the framework of this phase 2.4 *Research on ready-to-transfer existing technology and the use of by-products*:

1. **Updating the Biomass Energy Resources Atlas of the Philippines**
2. **Establishment of decentralized rice husk biochar production units in other producing regions**
3. **Decentralized heat production from rice straw: pellets and briquettes production**
4. **Establishment of one or more hydrochar production pilots and methanisation units using wet waste from vegetable production**

Projects 2, 3 and 4 are feasibility studies for the implementation of biomass energy production unit(s) by thermochemical conversion of lignocellulosic biomass through 3 main types of technical itinerary and proposed valorisation routes.

As a result, they will be structured identically, with the same headings, from the study of the supply of raw materials, needs and the market, socio-economic and environmental considerations, technical studies and the sizing of the project(s), the location of the units to be set up, the investment, financial and accounting aspects, the profitability study, the project implementation schedule, and the study of the project's risk and success factors.

These 4 projects are developed hereinafter.

3. Updating the *Biomass Energy Resources Atlas* of the Philippines

3.1. Background and justification

In the interests of energy security, the Philippines has for some years been promoting the development of available renewable energy sources such as hydroelectricity, geothermal energy, wind power, solar energy and biomass.

A number of policy decisions adopted by the government are scheduled to increase the country's use of renewable energies, and are included in the following reference documents: ***the Philippine Energy Plan 2018-2040. National Climate Change Action Plan 2011-2028 (chapter VI. Sustainable Energy).***

As far as biomass energy is concerned, the country's agricultural resources (rice, sugar cane, maize, coconuts, etc.) are mainly used to feed a growing population (1.5% per year and 115 million inhabitants by 2022).

These biomass resources generate consumable products and significant residue potential.

Some of these agricultural residues are used or wasted, but there are still large quantities that can be used sensibly.

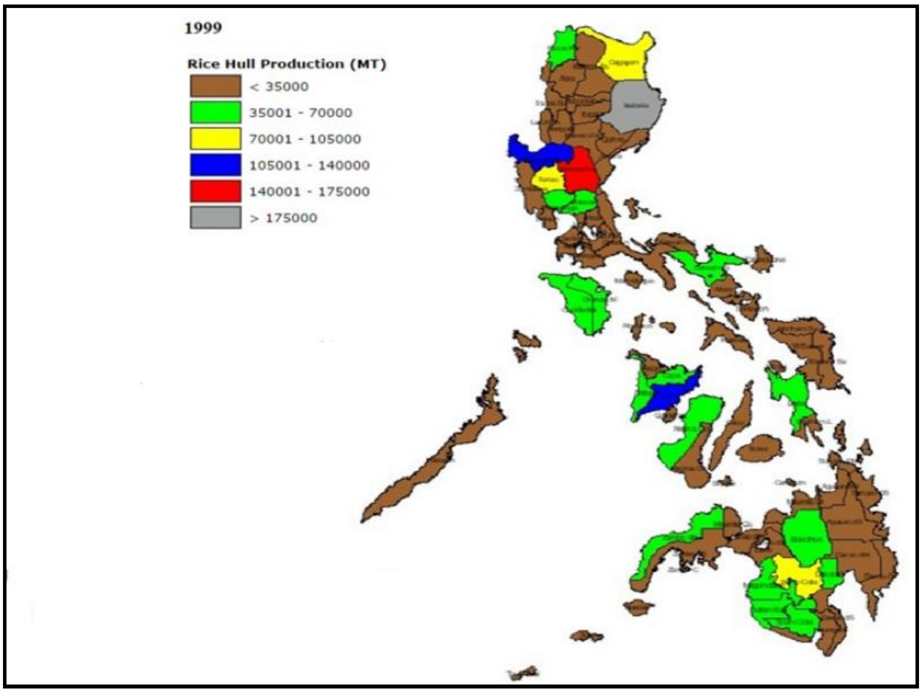
For many regions, this represents an opportunity to produce the energy needed by rural and urban populations, or to choose other means of recovery.

In 1999, a biomass resource assessment study carried out by the Institute of Agricultural and Biosystems Engineering (IABE) with US funding (National Renewable Energy Laboratory NREL; USAID) mapped resources at regional and provincial level using statistical data available at the time.

The main biomass-producing regions have been identified for six biomass resources: rice husk, bagasse, coconut residues, animal manure, forestry waste and urban waste.

The main result of this study is the production of maps associated with the Geographic Information System (GIS). In addition, processing centers that are point sources of biomass waste were located using GPS to obtain a more accurate estimate of the biomass resource and transport distances.

A geographical atlas was published in paper form ***(Biomass Atlas of the Philippines 2000)***.



Example of a map showing the distribution of rice husk production

3.2. Aims of the projet

The main aim of this project is to update this atlas with recent data, given the changes that have taken place over the last 25 years. Agricultural production of the various resources has increased significantly, and at the same time, biomass recovery units have been set up, such as BBEC Pili Camarines Sur (5 MWe), GIFT Nueva Ecija (12 MWe) and iPower San Jose City, NE, (12 MWe).

Updating such an atlas at regional and provincial level will make it possible to quickly visualize the locations of the various agricultural biomass resources and, consequently, the areas of agricultural by-product deposits that can be used for energy or other products.

Maps such as these, combined with a map showing the distribution of the population or energy requirements, will help in the decision making process as to whether or not to set up facilities to convert biomass into energy or other products (biochar, compost, etc.). Indeed, the logistics of collecting and transporting biomass by-products can be an obstacle to the development of biomass recovery projects because of the costs involved.

The size and feasibility of biomass processing facilities will also depend on the resource available and the logistical requirements for transporting it to a processing unit, in line with consumption sites and demographic distribution.

Depending on their quantity and quality, the biomass resources identified in an area will be suitable and sufficient to supply biomass conversion units.

3.3. Methodology

Geographic Information System (GIS) maps will be produced on the basis of the administrative map of the Philippines (regions, provinces, districts) and on the basis of regularly updated public data.

Additional field surveys in the various biomass-producing regions identified will help to refine the statistical data.

The Philippine Statistical Services Online (https://openstat.psa.gov.ph/) provides access to the various sections needed to produce reliable maps for the Atlas. These include detailed data by region and province, such as:

- Demographic and social data with annual trends.
- Economic data, particularly on agriculture, forestry and fisheries. These data are broken down annually, half-yearly and quarterly over several decades.

The Ministry of Agriculture https://www.da.gov.ph/ also distributes information that will be useful in drawing up these maps

Additional data is also available in various published documents, which include aggregate data on the overall quantities of biomass residues (rice, maize, coconut, sugar cane, municipal domestic waste, etc.).

Existing or planned biomass processing facilities, in particular energy production sites, will be listed on the Department of Energy website https://doe.gov.ph/

These sources of materials that can be mobilized for energy or other purposes in the short and medium term will be identified while respecting current uses so as not to destabilize or compete with existing recovery channels.

This project could be led by the University of the Philippines Los Baños and Central Luzon State University, in partnership with one or more complementary entities specializing in databases and cartography.

4. Establishment of decentralized rice husk biochar production units in other producing regions

Rice production generates two by-products, rice straw and rice husks.

As with straw, there are already a number of ways of recovering husk. Because of its properties, husk can be recycled in the form of energy (combustion, briquettes, etc.) or as a material (insulation, concrete additive, etc.).

In recent years, the development of biochar production from rice husks has been initiated by various producer countries in Asia and Africa, given the interest in this product, particularly for storing carbon in the soil while improving the productivity of certain crops by improving the soil.

The production of biochar from rice husks in the Philippines is in line with:

. the ***Philippine Development Plan 2024-2028*** (respectively Chapter 15 *Accelerate Climate Action and Strengthen Disaster Resilience* ... and Chapter 5 *Modernize Agriculture and Agribusiness).*

. the ***Philippine Energy Plan 2020-2040*** (chapter IX *environmental management*);

. the ***National Climate Change Action Plan 2011-2028*** (chapters III. *Ecosystem and Environmental Stability*).

4.1. Background and justification

Annual rice production in the Philippines is close to 20 million tonnes (FAO, 2024), generating around 4 million tonnes of rice husk. These husks, which are unevenly distributed across the country, are sometimes burnt by producers, which is no longer permitted by law.

Some of this energy is also transformed on an industrial scale at various energy production facilities, such as BBEC Pili Camarines Sur (5 MWe), GIFT Nueva Ecija (12 MWe) and iPower San Jose City, NE (12 MWe). These facilities, which are generally set up thanks to private investment, make it possible to limit the consumption of fossil fuels (oil or coal).

The production of compressed briquettes could be envisaged, but to date this has been the subject of small-scale work at a few universities or technical research establishments.

Finally, the production of biochar from rice husks offers a number of advantages in the Philippine context.

A number of laboratories are already involved in this approach (Department of Chemical Engineering University of the Philippines Los Banos, The Department of Agriculture - Philippine Rice Research Institute) through the development of small-scale pilots.

Meanwhile, in the town of Palayan, Nueva Ecija, ALCOM uses rice husks to provide local heat for drying cereals, while producing biochar. The biochar is mainly used to improve the quality of the soil by incorporating it into the soil.

The production of biochar in units distributed throughout the country would be in line with the objectives of the ***Intergovernmental Panel on Climate Change (IPCC)*** as an essential "negative emissions" technology for capturing CO_2 from the atmosphere, in line with the ***Philippine Climate Plan***, and would meet the objectives set out in the following documents:

. the ***National Climate Change Action Plan 2011-2028*** (chapter VI. *Sustainable Energy*);

. the ***Philippine Energy Plan 2018-2040*** (chapter IV. *Renewable Energy*);

and especially

. the ***Implementation plan for the Republic of the Philippines nationally determined contribution (NDC) 2020-2030*** (chapter 3. *Nationally Determined Contribution Implementation Plan* sub-chapter *Sector-Level Delivery of Nationally Determined Contribution Policies and Measures*)

BIOCHAR

Biochar is a carbon-rich solid produced by the thermochemical conversion of organic materials such as rice husks or another agricultural biomass.

This thermochemical conversion, known as pyrolysis, is an operation involving the chemical decomposition of an organic material by significantly raising its temperature in the absence of oxygen or in a low-oxygen atmosphere to prevent oxidation or combustion.

Biochar is a material with a growing number of applications in agriculture, environmental engineering and industry. For example, biochar is used to filter water, particularly in wastewater treatment, or to retain excess pollutants such as nitrogen or phosphorus.

In agriculture, the practice of growing crops on burnt land, which has been practiced for centuries, was put to good use by farming populations and still is in some countries. This practice, which has been revived in more modern agriculture in recent years through the introduction of biochar into the soil, enables carbon to be stored and, depending on the nature of the soil, improves its properties.

In addition, the porous, carbonaceous structure of the biochar improves nutrient retention in the soil via chemical exchanges between the biochar and the elements present in the soil. Biochar increases the water absorption capacity of soils, modifies pH levels and improves crop yields.

Finally, the quality of a biochar will depend on the quality of the starting biomass and the pyrolysis conditions, in particular the heating temperature, which is reflected in the H/C ratio (hydrogen/carbon).

4.2. Aims of the projet

The project will study the technical and economic feasibility of various pilot biochar production units using existing technologies.

The preliminary study of the quantitative availability of rice husks (see *Updating the Biomass Energy Resources Atlas of the Philippines* project) will determine the choice of sites for the installation of these units, which will have to be optimized according to the logistical constraints (distance to the resource, mode of transport, amount of storage). Beyond a certain transport distance, logistics costs can have a negative impact on the profitability of the project.

This project will be supported by the University of the Philippines Los Baños, PhilMec (Philippine Center for Postharvest Development and Mechanization), - PhilRice (Philippine Rice Research Institute).

4.3. Study methodology and areas to be covered

4.3.1. Study of the supply of raw materials

The following points will be covered:

* Areas and sources of supply (in relation to the *Updating the Biomass Energy Resources Atlas of the Philippines* project), maximum radius of supply to ensure economic viability of the project(s).

* Qualification, quantification and supply arrangements for rice husks: price and logistics costs (transport and packaging).

* Terms of association, cooperation and agreement with raw material producers.

4.3.2. Study of needs and the market

At present, only ALCOM in Palayan City, Nueva Ecija, manufactures biochar on an industrial scale. As mentioned above, some institutions have small-scale pilots.

The outlets for this production will be identified and described, together with the current state of demand, and changes in demand over the next 5 years will be estimated.

The comparative advantages of rice husk biochar produced by pyrolysis will be studied in relation to other additives and soil improvers, from a technological point of view and in terms of cost price.

4.3.3. Study of the acceptability of biochar in Philippines

The perception of the level of acceptance of this new soil amendment is an important component to take into account.

Knowledge of this perception by potential users will determine the information and communication campaigns that need to be put in place to demonstrate the comparative advantages of rice husk biochar compared with other soil improvers.

A survey will be conducted, taking into account the various barriers to trade formulated on the basis of the scientific literature published on the use of biochar. In particular, economic, technical, logistical, environmental and ecological barriers will be taken into account.

4.3.4. Socio-economic and environmental study

The contribution of the projects will be estimated on the following topics:

- economic: qualitative benefits, added value generated, jobs created,

- social: impact on local communities and populations, on their living conditions,

- environmental protection (protection and conservation of biodiversity, reduction of toxic emissions) in accordance with current regulations.

4.3.5. Technical study and sizing of the project(s)

Industrial production of biochar currently relies on a single facility, with a few laboratories operating pilot plants.

However, the technical and sizing study needs to be carried out thoroughly, as different technological options can be implemented. Pyrolysis is a tried-and-tested technology that can be considered on a variety of scales, involving equipment associated with highly variable production volumes.

The choice of equipment is therefore crucial, depending on the volumes of raw materials available and the level of production and marketing envisaged.

The choice of technology and production process will therefore have to be justified and argued in terms of the material and energy balances, the human resources required, an assessment of the cost of the work to be carried out (civil engineering, equipment, buildings), and the prospects for production.

The production unit(s) must be sized according to downstream demand and upstream raw material supply possibilities.

The study will describe the methods, logistics and equipment used to recover the rice husk upstream, and all the equipment needed for the transformation process(es): quantities, characteristics, capacities (main and auxiliary equipment), space requirements, potential suppliers.

Whatever the level(s) of production chosen, whether small-scale artisanal units or larger-scale units, an organizational diagram of these units will be drawn up specifying the layout of their various components: storage areas for raw materials and end products, processing area, premises, etc.

Among other things, the study will determine the ramp-up of operations and the optimum conditions for achieving this, as well as the staffing requirements, including the positions envisaged and the associated costs. It must also propose a plan for the supply, production and distribution of the project(s)' products that minimises operating costs and investment costs.

4.3.6. Location of the project(s)

The *Updating the Biomass Energy Resources Atlas of the Philippines project* will provide input for decisions on potential sites for pilot rice husk biochar production units.

Choices will also be justified in terms of cost control and socio-economic impact at local and/or regional level.

4.3.7. Investment costs

The investment cost study will consist of a detailed estimate of pre-operational and pre-launch expenditure, the estimated cost of acquiring land or the cost of leasing it, approach fees, the cost of buildings, equipment / facilities / infrastructure (including the cost of installing fluids) / rolling stock, as well as the working capital required to finance part of the short-term needs of the project(s).

The aim of this component of the study is to ensure that the profitability of the project(s) is based on the main estimated costs.

4.3.8. Financial and accounting study

The financial and accounting study will consist of analysing and presenting forecast estimates (over 5 years) of sales, costs (fixed and variable, loans, depreciation, etc.), and forecast cash flow (and project start-up). Depreciation schedules (loans, fixed assets) will be drawn up.

Based on the total amount of physical investment plus initial working capital and pre-operational costs, a financing plan will be proposed.

Sales based on the expected selling prices of the products manufactured, forecast operating expenses, forecast operating accounts and the use/resources table will be drawn up over a five-year period.

4.3.9. Profitability study and financing plan

The financial parameters of the project must be determined and a financing plan presented, including the identification and prioritisation of opportunities for the sources of financing envisaged: subsidies, Green Fund, carbon credits, international donors for environmental projects, etc.

4.3.10. Project schedule

The list and specifications of the activities to be carried out to set up the production unit(s) will be drawn up: estimate of the duration of each activity, estimate of the chronological order of the activities in the form of a bar chart, development of the general timetable for carrying out the project(s) up to the launch of production.

4.3.11. Study of the project's risk and success factors

The aim is to identify all the risks associated with the implementation of the project(s), including the supply of raw materials and energy, and to assess their criticality (frequency and impact).

Success factors will be identified and their impact estimated.

5. Decentralized heat production from rice straw: pellets and briquettes production

5.1. Background and justification

The use of rice straw appears to be more problematic than that of rice husks because of the dispersed nature of this agricultural by-product and the complexity of collecting and mobilising it.

Traditionally, this biomass was burnt on site, helping to improve the soil. Today, burning is theoretically prohibited.

The rice straw is left on site, contributing to soil fertilisation, but with a fairly slow degradation, due in particular to decomposition that is partly immersed, i.e. in an anaerobic phase.

It is also used as a raw material, often braided, to make small objects (baskets, containers, household utensils) but this type of recycling remains very marginal.

Briquettes and pellets production from rice straw will be effective solutions for decarbonizing energy in the Philippines and development of waste-to-energy technologies, in line with:

. the ***Philippine Development Plan 2024-2028*** (respectively Chapter 15 *Accelerate Climate Action and Strengthen Disaster Resilience* ... and Subchapter 2.3 *Establish Livable Communities Outcome 2: Environmental quality improved*);

. the ***Philippine Energy Plan 2020-2040*** (chapter II. *Energy Roadmaps / Renewable Energy & Alternative Fuels and Emerging Technologies* and chapter III. *Strategic Focus Areas / Environmental Management*);

. the ***National Climate Change Action Plan 2011-2028*** (chapters III. *Ecosystem and Environmental Stability and VI. Sustainable Energy*).

BRIQUETTES

The compression of lignocellulosic residues to produce agglomerated blocks is known as briquetting.

Compressing a product with a low density and a high degree of expansion will produce a product with a higher density that is cohesive enough to be transported, stored and used for energy purposes.

For this process to be effective, the compressed material must be made up of particles a few millimetres in size, and the moisture it contains must be evacuated.

Before being compressed, the residues are ground to obtain a homogenous material, which is then dried in kilns to lower its moisture content.

Main advantages of briquettes

* Better fuel than raw feedstock: more energy per unit volume, easy to use, compact and easy to store.

* “Clean” combustion

* Use of abandoned or burnt residues without energy recovery.

Main disadvantages of briquettes

* Relatively heavy investment in equipment

* Energy requirements (electrical) during the manufacturing process (between 70 and 300 kWh/t)

* Risks of other uses for the raw material and production overcapacity leading to price volatility

There are two types of solid densified products:

* Parallelepiped briquettes

* Cylindrical logs

PELLETS

Pellets are a fuel made from compacted (without glue or additives) and dried lignocellulosic residues.

A pellet is a small cylinder about 6 mm in diameter and 10 to 30 mm long.

Thanks to its very low moisture content (<10%), pellet has a high calorific value, making it an efficient source of energy.

Main advantages of pellets

* Storage is easier than with other energy sources.

* The small size of the pellets, their volume-to-surface ratio, their shape, their low moisture content and their homogeneity ensure that they flow smoothly through the feed systems and burn very completely, producing very few unburnt particles.

Main disadvantages of pellets

* They must be stored in a dry place so as not to lose their calorific value.

* They are still more expensive than charcoal or firewood.

* Their use requires a special firebox that is different from the charcoal firebox, and more expensive.

5.2. Aims of the study

The proposed project therefore focuses on increasing the energy density of the rice straw resource through the decentralised production of pellets or briquettes in the main producing regions (link with project *Updating the Biomass Energy Resources Atlas of the Philippines*).

A comparative inventory of the main existing production systems will enable us to select those best suited to the local socio-economic context.

The domestic market will be targeted, as well as VSEs, SMEs and SMIs, which are currently finding it difficult to secure their energy supplies.

One of the aims of the project will be to test the acceptability, production and marketing of these products under real conditions of implementation and use.

This project will be driven by the University of the Philippines Los Baños and Central Luzon State University.

5.3. Study methodology and areas to be covered

5.3.1. Study of the supply of raw materials

This part of the study will cover the following points:

* Qualification, quantification and supply arrangements for raw materials: nature, characteristics, quantities available, accessibility, suitability for mobilisation, transportability, suitability for storage, prices and supply costs.

* Areas and sources of supply (in relation to project *Updating the Biomass Energy Resources Atlas of the Philippines*), maximum radius of supply to ensure that the project(s) are economically viable.

* Terms of association, cooperation and agreement with raw material suppliers.

5.3.2. Study of needs and the market

For each of the two products envisaged, briquettes and pellets, the current state of actual production in the Philippines will be established, if it exists, and the associated biomasses currently used will be identified: wood or other natural or planted lignocellulosic biomasses, other agricultural by-products, including rice.

Current supply will be described, including market prices in the Philippines.

The outlets for this production will be identified and described, together with the current state of demand, and changes in demand over the next 5 years will be estimated.

The comparative advantages of the two products will be studied, as well as their advantages over other sources of bioenergy (direct burning, coal, biomethane, etc.), in terms of technology and cost price.

The profiles of the buyers/users (private individuals, VSEs, SMEs) will be defined as well as the corresponding potential distribution channels.

5.3.3. Study of the acceptability of briquettes and pellets in the Philippines

The perception of the level of acceptance of briquettes and pellets by users and potential markets - the domestic market, VSEs, SMEs, SMIs - is an important factor to take into account.

Knowledge of this perception will determine the information and communication initiatives that need to be put in place to demonstrate the comparative advantages of our products over other energy sources.

A survey will be carried out, taking into account the categories of barriers to trade formulated on the basis of the scientific literature published on the use of biomass.

In particular, economic, technical, logistical, environmental and ecological barriers will be taken into account.

5.3.4. Socio-economic and environmental study

The contribution of the pellet and briquette production project(s) will be estimated in terms of:

- Economic features: qualitative benefits, added value generated, jobs created, impact on foreign trade,
- Social impact: impact on local communities and populations, on their living conditions,
- Environmental protection (protection and conservation of biodiversity, reduction of toxic emissions) in accordance with current regulations.

5.3.5. Technical study and sizing of the project(s)

The manufacture of pellets and briquettes can be envisaged on different scales, using equipment associated with very variable production volumes.

For pellets, the smallest units for very localised production provide an hourly output of a few dozen kg (from 20-30 kg). For the largest industrial units, production can reach several dozen tonnes per hour (up to 40-50 tonnes per hour).

For briquettes, the largest units have a smaller capacity, up to a few tonnes per hour (5-6 tonnes maximum).

The choice of equipment is therefore crucial, depending on the volumes of raw materials available and the level of production and marketing envisaged.

The choice of technology and production process must therefore be justified in terms of material and energy balances, the human resources required, an assessment of the cost of the work to be carried out (civil engineering, equipment, buildings), and the outlook for production.

The production unit(s) must be sized according to downstream demand and upstream raw material supply possibilities.

The study will describe the methods, logistics and equipment used to recover rice straw upstream, and all the equipment needed for the transformation process(es): quantities, characteristics, capacities (main and auxiliary equipment), space requirements, potential suppliers.

Regardless of the level(s) of production chosen, whether small-scale artisanal units or semi-industrial or even industrial units, an organisation diagram for these units will be drawn up specifying the layout of their various components: raw material and end product storage areas, processing area, premises, etc.).

Among other things, the study will determine the ramp-up of operations and the optimum conditions for implementation, as well as the staffing requirements, including the positions envisaged and the associated costs. It must also propose a plan for the supply, production and distribution of the project(s)' products that minimises operating costs and investment costs.

5.3.6. Location of the project(s)

The potential location(s) will be studied, and their choice will be justified in terms of cost control, safety and socio-economic impact at local and/or regional level.

The status of the site will be specified and justified (rental or capital contribution status) as well as its legal situation.

The match between the production site(s) and the project(s) must be analysed.

5.3.7. Investment costs

The investment cost study will consist of a detailed estimate of pre-operational and pre-launch expenditure (including preparatory research and pre-investment studies), the estimated cost of acquiring land or the cost of leasing it, approach fees, the cost of construction, equipment / facilities / infrastructure (including the cost of installing fluids) / rolling stock, as well as the working capital required to finance part of the short-term needs of the project(s).

The aim of this component of the study is to ensure that the profitability of the project(s) is based on the main estimated costs.

5.3.8. Financial and accounting study

The financial and accounting study will consist of analysing and presenting forecast estimates (over 5 years) of sales, costs (fixed and variable, loans, depreciation, etc.), and forecast cash flow (and project start-up).

Depreciation schedules (loans, fixed assets) will be drawn up.

Based on the total amount of physical investment plus initial working capital and pre-operational costs, a financing plan will be proposed.

Sales based on the expected selling prices of the products manufactured, forecast operating expenses, forecast operating accounts and the use/resources table will be drawn up over a five-year period.

5.3.9. Profitability study and financing plan

The financial parameters of the project must be determined and a financing plan presented, including the identification and prioritisation of opportunities for the sources of financing envisaged: subsidies, Green Fund, carbon credits, international donors for environmental projects, etc.

5.3.10. Project schedule

The list and specifications of the activities to be carried out to set up the production unit(s) will be drawn up: estimate of the duration of each activity, estimate of the chronological order of the activities in the form of a bar chart, development of the general timetable for carrying out the project(s) up to the launch of production.

5.3.11. Study of the project's risk and success factors

The aim is to identify all the risks associated with the implementation of the project(s), including the supply of raw materials and energy, and to assess their criticality (frequency and impact).

Success factors will be identified and their impact estimated.

6. Establishment of one or more hydrochar production pilots and methanisation units using wet waste from vegetable production

6.1. Background and justification

A very specific category of agricultural by-products or co-products is currently under-utilised in the Philippines: wet to very wet waste. This includes vegetable production waste, such as that from the Benguet Agri-Pinoy Trading Center in Baguio.

In this collection centre, composting could be a suitable solution, but it is not used because of the lack of space and the nuisance associated with the degradation of organic matter (odour problems): on the Baguio plain, all the available land is given over to crops, so composting requires large areas.

Wet waste is difficult to recover in the form of energy because it first has to be dried, an operation that itself consumes a lot of energy. In this type of operation, the overall energy balance is hardly positive and the applicability of the valorization methods envisaged is not economically satisfactory.

Two types of technology can be considered for this type of wet waste:

1. Hydrochar production systems such as those developed by PhilMech are suitable for this type of agricultural co-product, in particular for vegetable production waste, but also for maize by-products with a high water content.

2. Methanisation in a digester in the absence of oxygen and in the presence of bacteria to produce biogas.

As with the biochar project, the production of hydrochar and the development of methanisation units are in line with the objectives of the ***Intergovernmental Panel on Climate Change (IPCC)*** as an essential "negative emissions" technology for capturing CO2 from the atmosphere, in line with the ***Philippine Climate Plan***.

In particular, the development of these valorization methods will contribute to the production of low-carbon energy and the development of waste-to-energy technologies, in line with:

. the ***National Climate Change Action Plan 2011-2028*** (chapter VI. *Sustainable Energy*);

. the ***Philippine Energy Plan 2018-2040*** (chapter IV. *Renewable Energy*);

and especially

. the ***Implementation plan for the Republic of the Philippines nationally determined contribution (NDC) 2020-2030*** (chapter 3. *Nationally Determined Contribution Implementation Plan* sub-chapter *Sector-Level Delivery of Nationally Determined Contribution Policies and Measures*).

HYDROCHAR

The production of hydrochar (hydrothermal carbonisation process, HTC, by converting biomass in water superheated to between 250 and 300°C under autogenous pressure) makes it possible to overcome the problem associated with the need to remove water from wet to very wet waste by adapting to a wide range of raw materials.

Hydrothermal carbonisation (HTC) is therefore a thermochemical treatment process specially designed for wet raw materials, where the biomass (with 80-90% water) is heated to a certain temperature at the saturation pressure of the water and maintained for a certain period of time.

In the Philippines, this technology can be used for agricultural co-products or by-products, such as waste from market garden production and by-products from maize processing, as well as various types of domestic waste.

METHANISATION

Methanisation is a technology for the controlled degradation of organic matter. It is a process carried out in a closed (anaerobic) environment.

It produces energy (biogas) and a residue called digestate, which is both a fertiliser and a soil improver.

The type of projects developed in agriculture is very varied.

The materials methanised are, in varying proportions, livestock manure, crop residues, inter-crop cover crops, etc.

The following criteria are generally used to characterise an anaerobic digestion plant (= digester) and assess the issues involved:

- unit size: tonnages of materials processed (between 8,000 tonnes/year for the smallest and 150,000 tonnes/year for the largest) and the unit's energy output;

- types and quality of materials treated: effluent, plant matter (including cuttings), industrial or household bio-waste, etc;

- source of materials and resilience to changes in the region: materials from the farms involved in the project, from the agri-food industry, from waste collectors in the region under contracts or through equity stakes in the anaerobic digestion plant;

- governance: individual or collective, private or public project, including local players (public or economic) or external industrialists;

- control of the operation of the unit: by the farmer(s) or by an external service provider;

- use of digestate: independent spreading plan or on external plots (or even export of ammonia), equipment used.

These various elements will be taken up and analysed in the feasibility study.

6.2. Aims of the study

* For the hydrochar component, the project will consist of studying the technical and economic feasibility of 2 to 3 pilot hydrochar production units using existing technologies, following a preliminary study of the availability of wet lignocellulosic by-products, mainly by-products from vegetable production (see project in Chapter 3 *Updating the Biomass Energy Resources Atlas of the Philippines*), but also by-products from maize processing and even other types of household or domestic waste. The preliminary study will determine the choice of sites for the installation of these units, which will have to be optimised according to the distance to the resource.

* For the methanisation component, the project will involve studying the technical and economic feasibility of 3 to 5 digesters using existing technologies, from which a choice will have to be made depending on the resources available.

The preliminary study of the availability of wet lignocellulosic by-products will be carried out jointly with the two hydrochar and methanisation components.

The preliminary study will determine the choice of sites for the installation of these units, which will have to be optimised according to the distance to the resource.

As far as hydrochar is concerned, the units to be set up will be of a pilot nature, as this type of technology is not yet fully ready for economically profitable production.

On the other hand, for the methanisation component, the digesters to be studied and set up will be operational and start production at the end of the project.

These projects will be supported by the University of the Philippines Los Baños, Benguet State University and the Benguet Agri-Pinoy Trading Center in Baguio.

6.3. Study methodology and areas to be covered

6.3.1. Study of the supply of raw materials

For both the hydrochar and methanisation strands, the following points need to be addressed:

* Qualification, quantification and supply arrangements for raw materials: nature, characteristics, quantities available, accessibility, suitability for mobilisation, transportability, suitability for storage, prices and supply costs.

* Zones and sources of supply (in relation to project *Updating the Biomass Energy Resources Atlas of the Philippines*), maximum radius of supply to ensure economic viability of the project(s).

* Terms of association, cooperation and agreement with raw material suppliers.

6.3.2. Study of needs and the market

The manufacture of hydrochar is currently only experimental in the Philippines.

On the other hand, methanisation units are already operating in the country.

The current state of actual biogas production will be established, and the associated biomasses currently used will be identified: wood or other natural or planted lignocellulosic biomasses, other by-products of agricultural origin, by-products of non-agricultural origin.

Current supply will be described, including market prices in the Philippines.

The outlets for this production will be identified and described, together with the current state of demand, and changes in demand over the next 5 years will be estimated.

The comparative advantages of biogas produced by anaerobic digestion will be studied in relation to other sources of bioenergy (direct burning, coal, biomethane, etc.), from a technological point of view and in terms of cost price.

6.3.3. Study of the acceptability of biogas from par methanization technology in Philippines

The perception of the level of acceptance of this type of energy and the associated potential markets - the domestic market, very small businesses, SMEs, SMIs - is an important factor to take into account.

Knowledge of this perception will determine the information and communication initiatives that need to be put in place to demonstrate the comparative advantages of biogas over other energy sources.

A survey will be carried out, taking into account the categories of barriers to trade formulated on the basis of the scientific literature published on the use of biomass.

In particular, economic, technical, logistical, environmental and ecological barriers will be taken into account.

The acceptability of hydrochar-type products will be studied simultaneously as part of the *Establishment of decentralized rice husk biochar production units in other producing regions* project.

6.3.4. Socio-economic and environmental study

The contribution of the projects will be estimated on the following basis:

- Economic: qualitative benefits, added value generated, jobs created, impact on foreign trade (only for the *methanisation* component),

- social: impact on local communities and populations, on their living conditions,

- environmental (protection and conservation of biodiversity, reduction of toxic emissions) in accordance with current regulations (only for the *methanisation* component).

6.3.5. Technical study and sizing of the project(s)

The manufacture of hydrochar is currently only a pilot project.

However, the technical and sizing study needs to be carried out carefully, as different technologies can be used, with parameters that vary according to the nature of the technical itineraries selected.

On the other hand, anaerobic digestion is a tried and tested technology that can be applied on a variety of scales, using equipment associated with highly variable production volumes.

There are many different types of digesters, depending on the feed method (batch, semi-continuous or continuous), the biogas storage method and the dry matter content of the substrate. This wide variety of processes means that they can be adapted to the characteristics of the substrate to be treated.

Each technology has its advantages and limitations. The best solution must therefore be determined on the basis of the technological requirements imposed by the situation.

The choice of equipment is therefore crucial, depending on the volumes of raw materials available and the level of production and marketing envisaged.

The choice of technology and production process must therefore be justified in terms of material and energy balances, the human resources required, an assessment of the cost of the work to be carried out (civil engineering, equipment, buildings), and the outlook for production.

The production unit(s) must be sized according to downstream demand and upstream raw material supply possibilities.

The study will describe the methods, logistics and equipment used to recover wet biomass upstream, and all the equipment needed for the transformation process(es): quantities, characteristics, capacities (main and auxiliary equipment), space requirements, potential suppliers.

Whatever the level(s) of production chosen, whether small-scale artisanal units or larger-scale units, an organisational diagram of these units will be drawn up specifying the layout of their various components: raw material and end product storage areas, processing area, premises, etc.).

Among other things, the study will determine the ramp-up of operations and the optimum conditions for achieving this, as well as the staffing requirements, including the posts envisaged and the associated costs. It must also propose a plan for the supply, production and distribution of the project(s) products that minimises operating costs and investment costs.

6.3.6. Location of the project(s)

For both the hydrochar and methanisation components, the potential site(s) for the pilot (hydrochar) or operational (methanisation) units will be studied, and their choice will be justified in terms of cost control, safety and socio-economic impact at local and/or regional level (this last point only for the methanisation component).

The match between the production site(s) and the project(s) must be analysed.

6.3.7. Investment costs

This phase of the study will only concern the methanisation component.

The investment cost study will consist of a detailed estimate of pre-operational and pre-launch expenditure, the estimated cost of acquiring land or the cost of renting it, approach fees, the cost of buildings, equipment / facilities / infrastructure (including the cost of installing fluids) / rolling stock, as well as the working capital required to finance part of the short-term needs of the project(s).

The aim of this component of the study is to ensure that the profitability of the project(s) is based on the main estimated costs.

6.3.8. Financial and accounting study

This phase of the study will only concern the methanisation component.

The financial and accounting study will consist of analysing and presenting forecast estimates (over 5 years) of sales, costs (fixed and variable, loans, depreciation, etc.), and forecast cash flow (and project start-up).

Depreciation schedules (loans, fixed assets) will be drawn up.

Based on the total amount of physical investment plus initial working capital and pre-operational costs, a financing plan will be proposed.

Sales based on the expected selling prices of the products manufactured, forecast operating expenses, forecast operating accounts and the use/resources table will be drawn up over a five-year period.

6.3.9. Profitability study and financing plan

This phase of the study will only concern the methanisation component.

The financial parameters of the project will have to be determined and a financing plan presented, including the identification and prioritisation of opportunities for the sources of financing envisaged: subsidies, Green Fund, carbon credits, international donors for environmental projects, etc.

6.3.10. Project schedule

This phase of the study will only concern the methanisation component.

The list and specifications of the activities to be carried out to set up the production unit(s) will be drawn up: estimate of the duration of each activity, estimate of the chronological order of the activities in the form of a bar chart, development of the general timetable for carrying out the project(s) up to the launch of production.

6.3.11. Study of the project's risk and success factors

This phase of the study will cover both the hydrochar and methanisation components of the project.

For the hydrochar component in particular, beyond the setting up of pilot units that are not intended to go into operational and economically profitable production in the immediate future, the aim will be to assess the real prospects for the development of this technology, the possible obstacles to it, and the areas where further research needs to be carried out in order to make this type of technology operational in the medium term.

For the methanisation component, on the other hand, it will be necessary to identify precisely and formally all the risks associated with the use of digesters, including the supply of raw materials, and to assess their criticality (frequency and impact).

Success factors will be identified and their impact estimated.

7. Conclusions

In the framework of the *Technical Assistance to Strengthen R&D for Climate Change Resilience of Agriculture in the Philippines*, Component 2.4 *Research on ready-to-transfer existing technology and the use of by-products*, the results obtained during the mission in the Philippines in March 2024 led to define and propose the four following projects:

1. Updating the Biomass Energy Resources Atlas of the Philippines
2. Establishment of decentralized rice husk biochar production units in other producing regions
3. Decentralized heat production from rice straw: pellets and briquettes production
4. Establishment of one or more hydrochar production pilots and methanisation units using wet waste from vegetable production

Projects 2, 3 and 4 are feasibility studies for the implementation of biomass energy production unit(s) by thermochemical conversion of lignocellulosic biomass through 3 main types of technical itinerary and proposed valorisation routes.

As a result, they are structured identically, with the same headings, from the study of the supply of raw materials, needs and the market, socio-economic and environmental considerations, technical studies and the sizing of the project(s), the location of the units to be set up, the investment, financial and accounting aspects, the profitability study, the project implementation schedule, and the study of the project's risk and success factors.

* The main aim of the project **Updating the *Biomass Energy Resources Atlas of the Philippines*** is to update this atlas with recent data, given the changes that have taken place over the last 25 years. Updating such an atlas at regional and provincial level will make it possible to quickly visualize the locations of the various agricultural biomass resources and, consequently, the areas of agricultural by-product deposits that can be used for energy or other products.

This project could be led by the University of the Philippines Los Baños and Central Luzon State University, in partnership with one or more complementary entities specializing in databases and cartography.

* The project **Establishment of decentralized rice husk biochar production units in other producing regions** will study the technical and economic feasibility of various pilot biochar production units using existing technologies.

This project will be supported by the University of the Philippines Los Baños, PhilMec (Philippine Center for Postharvest Development and Mechanization), - PhilRice (Philippine Rice Research Institute).

* The project **Decentralized heat production from rice straw: pellets and briquettes production** focus on increasing the energy density of the rice straw resource through the decentralised production of pellets or briquettes in the main producing regions (link with project *Updating the Biomass Energy Resources Atlas of the Philippines*).

This project will be driven by the University of the Philippines Los Baños and Central Luzon State University.

* The project **Establishment of one or more hydrochar production pilots and methanisation units using wet waste from vegetable production** is organized into two main components related to (1) hydrochar production and (2) biogas production by methanisation.

. For the hydrochar component, the project will consist of studying the technical and economic feasibility of 2 to 3 pilot hydrochar production units using existing technologies, following a preliminary study of the availability of wet lignocellulosic by-products, mainly by-products from vegetable production, but also by-products from maize processing and even other types of household or domestic waste.

. For the methanisation component, the project will involve studying the technical and economic feasibility of 3 to 5 digesters using existing technologies, from which a choice will have to be made depending on the resources available.

These projects will be supported by the University of the Philippines Los Baños, Benguet State University and the Benguet Agri-Pinoy Trading Center in Baguio.

The costs of implementing the four projects, updating the *Biomass Energy Resources Atlas of the Philippines* and the three feasibility studies are not mentioned in this report.

They will be detailed in the four corresponding summary sheets (Xls files) that follow.