WABEF: Western Africa Bio-wastes for energy and fertilisers

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Biogas Transpaille unit at AEDR, Mali. Photo by René van Veenhuizen

Population growth and urbanisation, along with changes in lifestyle and consumption, lead to large quantities of solid and liquid organic waste from agricultural, agro-industrial and urban activities. In the absence of an adequate waste management system, these can cause harm to human health and the environment. Biogas technologies are unique among renewable energy forms in that they address several challenges in Sub-Saharan Africa in an integrated manner. They enhance the connections and potential synergies between sectors. WABEF – Western Africa Bio-wastes for Energy and Fertilizer - has promoted anaerobic digestion as a way to recycle bio-wastes for energy and fertilisers. As such, the organic matter loop is closed.

At present West Africa has a very low electricity use per capita, but this situation is likely to change rapidly in the future: demand is projected to increase ten-fold in the coming two decades as economic activity increases and universal access is achieved. A power sector transition is required and actually has started. Africa does have an abundant potential of bioenergy in the form of plant and animal residues among others or bio-wastes, which is in principle enough to satisfy the national demand for electricity. But still around 850 million people cook and heat their homes using open fires and simple stoves burning biomass (wood, animal dung and crop waste) and coal. Opportunities exist to use available biomass sustainably.

ECOWAS/ECREEE suggest that up to 54% of Western Africa's power supply can be based on renewables in 2030 (that includes hydro-power). Most ECOWAS countries have set targets of a use of 10% to 20% renewable energy (excluding hydro-power) in 2020 and 2030 respectively.

Adoption of renewable energy in developing economies is growing at about twice the rate of industrialized economies. Renewable energy sources most used for large-scale applications are hydropower, biomass, geothermal, wind and solar energy sources, with these being usually grid-connected.

The technologies needed for tapping into Africa's renewable energy resources are available, reliable and cost-competitive. Various innovative uses of bio-wastes have been introduced and tested, such as domestic or community-managed biogas projects, or using food-wastes or waste from agroindustry. With increased efficiency of use and better technologies, significant power can be produced for local demand or added to the national grid. Several agriculture-based industries in the continent, such as wood-based including paper industries, palm, rice and sugarcane mills use their waste to produce both process heat and power, which in most cases is used locally. Somewhat larger-scale biogas plants also operate successfully in a number of African locations. Most urban areas in Africa face serious problems with disposal of liquid and solid bio-wastes, which could be converted to energy, while also producing organic fertiliser.

Bio-wastes, or "Residual Organic Products", in the broad sense, are biodegradable wastes derived from agricultural, agro-industrial and urban human activities. These include crop residues, manure, slurry, abattoir waste, garden or park wastes, food or kitchen wastes, waste from food processing and sewage sludge.

The potential of using bio-wastes for energy and fertiliser is based on the accumulated bio-waste volumes. However, in most countries this is hardly known and quantified. Policy makers and entrepreneurs lack sufficient information on how and where to start a business or formulate a workable policy. WABEF has therefore developed operational tools for each step of the value chain, as set out below.

Mobilising the necessary investments will require governments and other stakeholders to work towards an environment that is built on an enabling policy and regulatory framework. In 2005, the Biogas Africa initiative was launched in Nairobi. Since then, many stakeholders have engaged in different initiatives and partnership programs supporting development of biogas technology in Africa. Ghana, Kenya, Niger, Burkina Faso, Mali, Ethiopia, Senegal and Rwanda have implemented pilot projects aimed at establishing the technical and socio-economic viability of biogas technology as an alternative source of energy for cooking and decentralised rural electrification. However, only a few countries have managed to start implementing their frameworks.

But there are other hurdles for upscaling and dissemination of good practices in Sub-Saharan Africa. These include constraints on mobilising bio-wastes, high initial investment costs for construction, insufficient maturity of national biogas programs, as well as technical, institutional and socio-cultural barriers.

The WABEF answer

WABEF – Western Africa Bio-wastes for Energy and Fertiliser was a research-development and capacity-building intervention funded by the ACP-EU Science & Technology II programme. Its aim was to recycle organic residues issuing from agriculture, agro-industries and municipalities into energy and fertiliser (http://wabef.cirad.fr).

Biogas technology is unique among renewable energy sources in that promoting its development in West Africa will support the environmental, energy and agricultural sectors:

- It reduces the pressure of bio-wastes on the environment by recycling them into biogas plants; this produces energy for cities and reduces deforestation by limiting the supply of wood and coal from rural areas
- It contributes to the satisfaction of energy needs in a complementary mix with other sources of conventional and renewable energies
- It closes the organic matter loop through the production of bioslurries as fertiliser returned to agricultural production areas; this addresses agricultural productivity and food security issues.

WABEF worked with various target groups, like decision makers, researchers, NGOs and technicians in agriculture, municipalities and agro-industries. Collectively they reached out to communities, students, entrepreneurs, and farmers. The key output of WABEF is a decision-support toolkit on anaerobic digestion of bio-wastes in West Africa.

Activities and products

As a first step WABEF analysed experiences in Europe and in Africa. Thirty-four anaerobic digestion experiences in Europe (14) and Africa (20) were visited by a broad team of representatives from the project partners, to learn about technological and managerial successes and failures, but also political and regulatory incentives and disincentives. It

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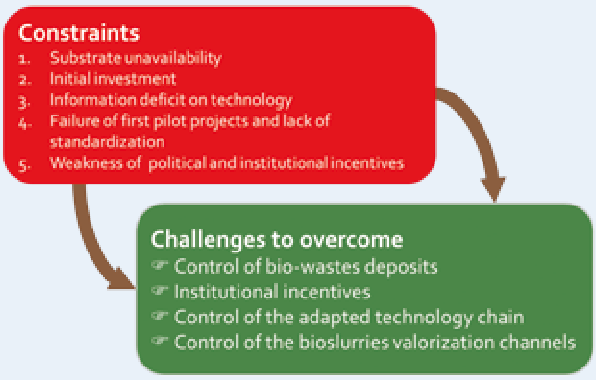
also assisted in developing a typology of biogas.

WABEF identified the key technical indicator for this typology. It relates the nature of the bio-waste intake with the annual quantity processed in the biogas unit and the electric power delivered. This was useful to compare relevant experiences of: less than 3,000 T/year and 50 kW; between 3,000 and 10,000 T/year and between 100 and 500 kW; and above 10,000 T/year and 500 kW. For each category an experience was documented. (http://wabef.cirad.fr)

Three main lessons emerged out this study. The first is the need to secure the bio-wastes supply to ensure its smooth operation and durability. The second is to have policy and regulatory frameworks that provide incentives for attractive tariffs for the purchase of by-products -- in particular biogas and electricity -- and that promote technologies consuming these by-products. The third lesson, related to the first, is to secure the flow and recovery of bio-wastes in order to minimize the risks of environmental pollution; this also avoids loss of income for the unit and maintains its good reputation.

The development and adoption of biogas as a solution for the management of bio-wastes in West Africa requires a favourable political climate and strong government support; that includes proper financial support for businesses and investment. An integrated approach must also enable proper management of information, an adapted technology chain, and sufficient bio-waste resources: where and when are they available, in what amounts, and with which energy and agronomic potential, and what is the competition? The recycling of bio-slurries must also be facilitated. The compendium guides the reader, whether practitioner, project promoter or policy maker, into these constraints and challenges. It also guides them on the appropriate tools that have been adapted by WABEF to support the assessment of each step of the biogas value chain.



Constraints of biogas development in West Africa and challenges to overcome

Toolbox / decision support systems

As a second step, and relying on the operation of the value chain, the project adapted a variety of existing items to develop a toolbox. This made it possible to characterise or evaluate each step of the value chain and its feasibility (see figure). For each of these steps WABEF proposes an operational tool allowing answers to the questions: *Availability* of bio-wastes? For *which biogas system? What valorisation* for biogas? *Use of bio-slurry* or digestate? Is the whole value chain *feasible?* And what *knowledge and know-how are needed for decision makers and practitioners?*

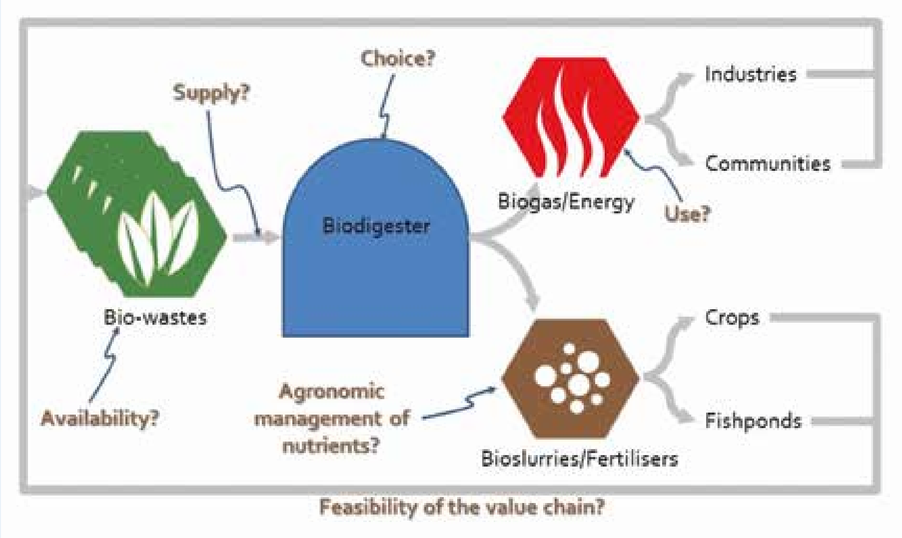


Figure: Questions to be answered to support decision-making and a viable business plan.

Availability of bio-wastes

In West Africa, little information on bio-waste deposits and their quality are available. Their appropriateness raises questions. A method to identify, quantify and assess their potentialities in term of fertilisation and production of biogas has been developed in the form of three databases. These estimate the deposit of bio-wastes from agricultural activities (crops and livestock), the deposit of bio-wastes from municipal activities and the deposit of bio-wastes from agro-industrial activities. Combining available information at district level on livestock and cultivated areas allows one to get a rough or theoretical deposit related to the assessment of the valorisation ratio one reach the agricultural bio-wastes deposits available for biogas. Municipal bio-wastes can be obtained through national census data of population at the district level combined to production ratio of household waste, use of improved or unimproved sanitation facilities

Biogas production depends on the quantity and quality (biochemical methane potential) of the bio-wastes. WABEF has done this in collaboration with *Institut Sénégalais de Recherches Agricoles* (ISRA) and the support of the Biogas National Programme (BNP) of Senegal and.

The data necessary for such calculations are dispersed, often difficult to access, and generally poorly organized. The re-use of bio-wastes as agricultural fertilizers and energy- using biogas technologies requires proper management of these resources. Governments should introduce a systematic approach to the collection and dissemination of statistics on bio-wastes at various levels and sectors, with an identified focal point.

Supply

To answer the question "what supply for a unit of collective biogas?" simulation tools exist (designed by CIRAD, Research Unit *Recyclage et Risque*) and can be used in West African conditions. The objective for a biogas operator is to be able to coordinate the quantity and quality of bio-waste supply to the biogas unit in order to allow its nominal operation. Different supply strategies (planned or reactive) and logistic options (truck number and capacity, route, working time, etc.) can be tested, depending on the characteristics of the biogas unit, including hazards. These strategies and options can be compared using indicators of the amount of residues actually delivered to avoid bio-waste stock shortages at the biogas unit, working time, kilometres travelled). These tools can be used to inform preliminary projects.

Photo by Maurice Kamate

WABEF multi stakeholder meeting in Dakar. Photo by René van Veenhuizen

Biogas technology

The model of technical-economic analysis of biogas: *Methasim©* developed by IFIP (*French Institut du Porc*) has been adapted for use in West Africa. A biogas project owner needs to make a reasoned choice of which technology to implement for a specific context. This tool allows one to test different intake ratios and technical options to calculate mass balances and economic balances for different biogas technologies. The user can then compare them. This tool can support actors in the development of their preliminary project.

Use of biogas

The biogas product from the biogas production process is composed of 50-80% of methane (CH_4), 20-40% carbon dioxide (CO_2) and 0 to 3% other gases such as hydrogen (H_2), nitrogen (N_2), hydrogen sulphide (H_2S), carbon monoxide (CO). This composition is closely related to the composition of the bio-waste intake of the digester. The methane content of the biogas allows the production of energy.
The valorisation of the biogas produced by a biogas unit depends on the purpose for which the unit was installed, the volume of biogas produced, the energy needs of the site and the project holder, possible outlets, etc. The seven uses are (i) heat production, (ii) electricity production, (iii) co-generation (heat and electricity), (iv) injection of bio-methane into the city gas grid, (v) injection of electricity and bio-methane into grids, (vi) bio-methane fuel or natural gas vehicle and (vii) tri-generation (heat, cold, electricity).

WABEF has designed a simple calculation tool to assess the use of the biogas directly or through electricity generation. It is available as a Microsoft Excel® spreadsheet in English and in French. The part of the business plan on financial parameters was more easily placed in a separate sheet that could immediately render the financial results. This was enthusiastically received by practitioners interviewed as they had never obtained such insight in their social business of biogas before.

Agronomic management of released nutrients

After the anaerobic digestion process and its storage, the bio-slurry is sanitised and deodorized. The germination power of weed seeds is also annihilated. The fertilising and soil-conditioning properties of the bio-waste intake are preserved or even optimized in the sense that its major nutrients (nitrogen, phosphorus and potassium or NPK) can be used.

Bio-slurries can be valued as:

- Raw bio-slurry for direct application to agricultural soils. This is the general practice in Europe
- Compost. The raw bio-slurry is composted with a carbonaceous support (straw, wood chips, green waste, etc.) Composting eliminates pathogens that would not have been eliminated during biogas production. And this is the only way, especially in France, to obtain a standardised product that escapes the status of waste regarding regulation
- Liquid fertilising material. The liquid fraction obtained after phase separation can be evaporated or filtered to reduce the water content and produce less bulky solutions rich in nutrients that can serve as liquid fertiliser. This liquid fraction also allows recovery, by stripping nitrogen, of a concentrated solution of ammonium sulphate; and by precipitation of the phosphate and ammonium ions, struvite crystals
- Inoculum. The liquid fraction is reintroduced into the anaerobic digestion reactor to catalyse and stabilise the methanisation process.

Photo by René van Veenhuizen

The utilisation of bioslurries as a fertiliser benefits both farmers and the environment. By applying bioslurries on soils, the nutrients contained in the bio-waste intake are brought back into nature to be incorporated into new organisms and to continue their cycle. By replacing mineral fertiliser with local fertiliser, farmers will enjoy financial gains. The clear picture of the advantages regarding the application of bioslurries as a fertiliser stays, however, in the shadow of regulations – at least for now.

WABEF designed a user-friendly Microsoft Excel® spreadsheet, *Ferti-Mbaay*, a calculator to support farmers fertilising with organic residues including bioslurries. This tool guides the fertilisation of market garden crops, but can be developed to include new crops and new organic residues. The development of this tool raised questions about the availability of the data necessary to implement this simple calculation.

Biogas technologies cannot be developed without institutional support at national and local level. Subsidies for installation of biogas units are needed to support further development and its sustainability, but also mixes of finances for equipment and recovery of by-products (fertilisers and biogas).

Feasibility of the whole value chain

A business model canvas for the biogas system should have the following features:

- Comprehensive in terms of looking at the whole biogas value chain
- Easy to fill in for the practitioners
- Fit both commercial and non-commercially-operated systems
- Provide practitioners and operators with insight on improvement, cost reduction and income enhancement.

WABEF's spreadsheet format (Microsoft Excel®) in French and in English proposes a business model to address the feasibility of the value chain.

Bio-wastes for energy and fertilizer (BEF) business canvas

A business model framework for social enterprises identifies how an organisation can create economic, social and environmental value (Osterwalder, 2004). It turns generic questions into biogas system-specific ones. The model allows for easy manipulation and also the addition of appraisal, monitoring or evaluation numbers. It can then be used to value the information in the reply to the question. The model was tested on the two demonstration biogas systems at AEDR-Teriya Bugu in Mali and at Songhai Regional Centre in Benin. Both are partners of the WABEF project.

Two other qualitative models are suggested to analyse sustainability and maturity.
The FIETS model has been developed in the Dutch WASH alliance project (www.washalliance.nl), and adapted by RUAF. This model aims to assess the progress and sustainability of a project or programme, looking at financial, institutional, environmental, technical and social aspects. This exercise is therefore based on the evaluator's knowledge of the project and should follow a number of suggested recommendations (stand-alone project evaluation, comparison of a range of projects, monitoring and evaluation or post evaluation).

The other tool is developed by the FACT Foundation for larger biogas programmes in Africa. The Product Market Cluster Tool for policy makers and strategists was adapted for WABEF. It looks at the BEF potential and available knowledge to policy makers or strategists, aiming to provide data for policy-makers and strategists to develop adequate policies.

Photo by Maurice Kamate

Any such new activity for a business sector can only be successfully introduced if that sector is stable and preferably growing; this affects the willingness and ability of the business owners to invest in new BEF systems. The strategists or policy makers need to take a number of steps to establish a good basis for policy and strategy development: potential clusters definition; selection of priority clusters; selection criteria to be used; features of the selected clusters.

Biogas can contribute to the energy needs of West African countries as part of a locally-appropriate (renewable) energy mix, while addressing a number of other sectoral challenges. It is therefore important to stimulate integrated planning and coordination processes to overcome sectoral approaches.

An integrated approach

Promoting the integrated development of anaerobic digestion is not to promote one technology or one model, but to offer to the stakeholders the key elements to support reasoned choices for developing an integrated and viable biogas value chain.
The successful fixed domestic dome bio-digester cannot be up-scaled to all localities, especially in urban and peri-urban areas, for reasons of space, safety and public hygiene. But it triggers the start of the sector, and is part of the RE mix.

In West Africa, particularly in Senegal, Mali, Burkina Faso and Niger, wood energy is the main fuel used by 90% of households. Demographic pressure, particularly urban, and poverty intensify this use and contribute to forest degradation. The city of Bamako, 5.4 million inhabitants, consumes 884,491 tons of wood-fired equivalents annually (Fonabes, 2017). Reducing deforestation entails the search for alternatives. Mobilising bio-wastes from municipal solid waste, faecal sludge and sewage sludge to produce biogas in one or more semi-industrial or industrial units could substitute coal and wood for urban populations. The anaerobic lagoon of Ashaiman Slum, Greater Accra, Ghana is an example.

In more isolated rural, domestic and agricultural situations, the small individual household bio-digester can play a role in contributing to the well-being of people, especially women and young people. It creates a better lifestyle through clean cooking and lighting, but the supply of bio-wastes must be secured year-round. At the scale of a rural community or groups of farmers, biogas of semi-industrial size could bring economic development.
Large biogas units require large investments, but they also allow economies of scale and can cover all possible recovery routes for biogas and digestate. But the economic, environmental, social and political sectors must be on the same level of technology readiness.

At local level access to information on the availability of organic resources and the use of by-products are needed. Information as well as access to various sources of financing and appropriate technologies should be facilitated through local incubator centres. The establishment of these decentralised support structures will bring together local authorities, technical services and communities.

Capacity building

WABEF actively disseminated its knowledge in selected countries in West Africa. In July 2017 a regional school was organised at Songhaï (Benin), gathering selected high-level actors from Benin, Cape Verde, Mali and Senegal. They have been trained in the use of the WABEF toolbox and are responsible for further uptake and dissemination. Further information, including a policy brief is available at its website. A curriculum for practitioners and university training will be further developed for dissemination in specific master's programs in West Africa.

The development of biogas in West Africa requires a favourable political climate and strong government support; that includes proper financial support for businesses and households' investment. An integrated approach must also enable proper management of information and waste resources as described above. Furthermore, innovative information and capacity building approaches are needed to support the private sector, governments and civil society to enable wider adoption and dissemination of biogas as part of a further increase in its proportion of RE in Africa.

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