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The LabTogo-Project

Analysis of the biomass potential and set-up of research capacities for the development of a biogas sector in Togo

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Abstract. A joint project between West African Science Service Center on Climate Change and Adapted Land Use (WASCAL), the University of Lomé and the German Biomass Research Center (Deutsches Biomasseforschungszentrum; DBFZ) was initiated in 2020. The project aims at evaluating alternative and regenerative energy sources for rural areas and creating the basis for successful implementation. In three different work packages, therefore, biomass potentials should be quantified, technologies should be examined with regard to their suitability and - in the case of biogas application - a research structure, pilot biogas laboratory, should be created that is necessary to enable the sustainable implementation of technologies.

Keywords: biomass resource mapping, sustainable development, biogas research capacities

Introduction

Togo is one of the West African countries that is establishing research activities for sustainable development in the context of the German-African research cooperation West African Science Service Center on Climate Change and Adapted Land Use (WASCAL). The development of research infrastructure and transfer of knowledge for the bioenergetic use of agricultural, forestry and organic residues are essential in order to implement measures against climate change and to significantly reduce deforestation or, at best, to stop it.

In 2020, the Federal Ministry of Education and Research (BMBF) initiated a joint project between WASCAL, the University of Lomé and the DBFZ. The project aims at evaluating alternative and regenerative energy sources for rural areas and creating the basis for successful implementation.

In a first step, therefore, biomass potentials should be quantified, technologies should be examined with regard to their suitability and - in the case of biogas application - a research structure should be created that is necessary to enable the sustainable implementation of technologies. Accordingly, the project focuses on three subject areas and sets the following objectives:

- Analysis of the potential system contribution of biogenic resources
- Construction and commissioning of a biogas laboratory as well as corresponding training courses
- Studies on alternative methods for cooking stoves

A kick-off meeting was held in July 2020 as a virtual web meeting due to the COVID-19 pandemic. Since then, all partners involved have worked together on the implementation of the project goals. Despite the ongoing complex situation, which for example severely restricts travel opportunities, progress has been made in all work three work packages. The project structure is shown in **Figure 1**.

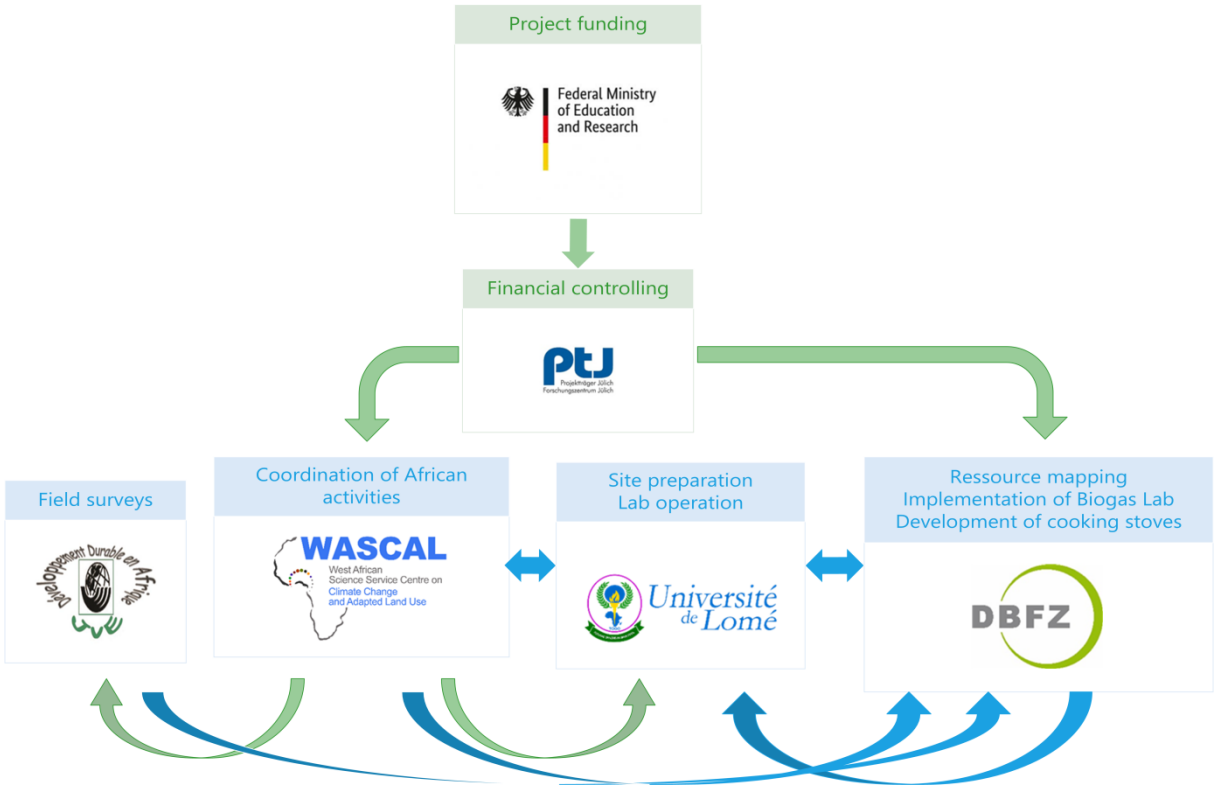

Figure 1: Structure of the project (green arrows: funding, blue arrows: information and product flow)

Work package 1: Analysis of the potential system contribution of biogenic resources

The system contribution of biomass depends largely on the availability and mobilization potential of existing resources. Therefore, work package 1 aims at a comprehensive systematic assessment of the expected impacts that the technologies considered in the project would achieve if they were established on a broad scale in Togo. To achieve this, three main activities have been defined: Acquisition of spatial information on biomass availability, assessment of suitable technologies and estimation of potential GHG emission savings.

Acquisition of Spatial Information for the Identification of Preference Regions

In a first step, freely available MODIS MOD12Q1 satellite datasets captured between 2001 and 2019 were acquired and analyzed in order to identify land-cover/land-use changes in Togo. We used Change Detection analyses to quantify the extent of relevant changes as well as to locate areas exposed to significant expansion of agricultural fields, urbanization or the loss and degradation of natural vegetation. Due to the high level of thematic detail in MODIS MOD12Q1 datasets, changes between 17 individual land-cover types can be identified on a yearly basis.

In addition to that, open geospatial data products derived from Global Forest Watch (GFW) as well as the International Food Policy Research Institute’s (IPFRI) global database on 42 spatially-disaggregated crop production statistics are used to determine locations exposed to significant tree cover losses and intense utilization of farm land. Agricultural production values extracted from IFPRI’s Spatial Production Allocation Model (SPAM) support the quantification and identification of areas with high biogenic residues. Furthermore, information about temporal changes and trends in agricultural production can be extracted and evaluated.

Additionally, the biomass potential, particularly that of agricultural by-products and organic wastes generated by markets and the food industry, will be mapped and evaluated in terms of quantity and spatial availability. To this end, the Togolese partners conducted extensive field work following a methodological procedure joint prepared with DBFZ to establish a sound database on point sources of large production sites. The objective of the current activity is to update data collected during the feasibility studies on the biomass potential in different regions of Togo. Data to be collected with high accuracy include local primary data (primary data on biogenic residues from agriculture, food processing and municipal waste) and the characterization of household wastes for the construction of biogas plants and pyrolysis.

Table 1 below summarizes the type of wastes to be collected in each region and their priority and Table 2 the farm/livestock/industries scales to be considered regarding each category of waste. The data are collected per point source with their coordinates and the amounts of wastes, byproducts, etc. were estimated based on conversion factors.

Table 1 Types of prioritized wastes in each region

Region	Types of wastes	Priority
Savanes	▪ Animal husbandry wastes/animal market ▪ Slaughterhouses wastes ▪ Rice bales/cooperatives/industries ▪ Rice straws ▪ Market ▪ others	Priority 1
	▪ Human sludge	Priority 2
Kara	▪ Animal husbandry wastes/animal market ▪ Rice bales/cooperatives/industries ▪ Rice straws ▪ Industries (brewery) ▪ Slaughterhouses wastes ▪ Market (Ketao) ▪ others	Priority 1
	▪ Human sludge ▪ Household waste characterization	Priority 2

Region	Types of wastes	Priority
Plateaux	▪ Animal husbandry wastes/animal market ▪ Rice bales/cooperatives/industries ▪ Rice straws ▪ Slaughterhouses wastes ▪ Fruits market ▪ Cotton industries ▪ Pineapple residues from farms ▪ Palm nut residues ▪ Wastes from woodwork ▪ Others	Priority 1
	▪ Human sludge ▪ Household waste characterization	Priority 2
Maritime	▪ Animal husbandry wastes/animal market ▪ Rice bales/cooperatives/industries ▪ Rice straws ▪ Slaughterhouses wastes ▪ Palm nut residues ▪ Market ▪ Fruit industries (Gbatope, Adangbe, etc.) ▪ Pineapple residues from farms ▪ Waste from woodwork ▪ Others	Priority 1
	▪ Slaughterhouses wastes ▪ Human sludge	Priority 2
Lomé	▪ Animal husbandry wastes/animal market ▪ Slaughterhouses wastes ▪ Human sludge ▪ Fruit market ▪ Cereal flour industry ▪ Fruit/juice industries ▪ Oil industries ▪ BB/SNB- breweries ▪ others	Priority 1
	▪ Household waste characterization	Priority 2

Table 2 Minimum size of the farm/livestock and other type of data scales

Types of wastes	Scale	Surveys’ procedures
Animal Farms/market	A minimum of: 1000 heads of poultry or 50 heads of cows or 200 heads of cattle/goats	- identify the farms through regional authorities or ongoing projects - number of farms to survey/markets - type of use of the waste
Industries (rice, fruits/juice, cashew fruit, cotton, oil, cereals)	All producing food-processing industries producing organic wastes	- identify the farms - quantitative evaluation of wastes and current uses
Rice straws (rice farms)	>30 ha in one set	- identification - quantification of the residues - type of use of the waste

Pineapple farms	>1 ha in one set	- identification - quantification of the residues - type of use of the waste
Fruits market; Industries (brewery); Slaughterhouses wastes		- systematic surveys - type of use of the waste
Human sludge	No scale	- Type of use of the waste

All gathered information will contribute to the identification of priority areas for preferential regions for the construction of biogas plants and regions for the mobilization of biomass for pyrolysis. A GIS-based hot spot analysis based on the point sources obtained in the field will further provide important spatial information to narrow down potential locations for sustainable biomass conversion and therewith an effective production of biogas and for pyrolysis. Advanced site assessments will analyze the respective catchment area, availability of agricultural residues and biomass by-products as well as infrastructural parameter (i.e. electrification, transport distances). Based on this information, biomass supply curves will be calculated for the identified sites, representing the relationship between biomass availability and transport distances. The biomass supply curves enable assumptions on which plant size classes would be suitable for the identified sites.

Assessment of Suitable Conversion Technologies

In a second step, different technologies including pyrolysis will be assessed. The aim is to provide general assumptions on the specific biomass substrates regarding their specific utility for the biogas process and for the pyrolysis cooker and to point out the necessary technical preconditions (e.g. substrate preparation). In this context, a broad regionalization for different technological concepts aligned to specific local needs (e.g. electricity supply, heat generation, cooking gas) will be carried out, so that appropriate technical solutions can be presented to the respective local stakeholders. Cost calculations for the establishment of the identified technological concepts and investments for indispensable required infrastructure are then developed in dependence of the site conditions. The derivation of specific production costs will enable an evaluation of the different technological solutions and a statement of their cost-effectiveness for each site and their competitiveness taking into account local market conditions. Subsequently, an economic technology impact assessment is needed to be aware of possible negative side effects.

Estimation of the GHG Emission Savings Potential

In a third step, local a national emission reduction effects are estimated for the identified material flows. Thereon, saving effects are determined that result from the substitution of the energy sources used to date in the different sectors (e.g. energy production, energy for cooking, etc.). The quantification of these saving effects in combination with the estimated amounts of available biogenic resources then allow for assumptions to be made about the potentially achievable energy savings at the national level and about the possible benefits of using biogenic resources in the various sectors of use. Finally, a calculation tool will be developed that will enable the evaluation of the energy savings and the relevance of substituting energy sources in the various sectors of use.

Work package 2: Construction and commissioning of a biogas laboratory and capacity building

The establishment of a ready-to-use biogas laboratory at the Université de Lomé is a central component of the project. The laboratory will serve to implement the results of work package 1 and to accompany and support the development of an own biogas sector in Togo through applied research. In addition, it will be used for the training of students at the University of Lomé and other stakeholders in West Africa.

The basic concept and the details of the equipment were designed in close cooperation with the University of Lomé. In order to save costs, the laboratory building is designed as a container construction. The individual containers will be largely pre-assembled in Germany and connected to form a complete building at the final location. The building will consist of six 20-foot laboratory containers as well as a refrigerated container that will serve as a cold storage room for samples. Each container contains a special laboratory area such as sample preparation, analysis room or biogas test reactors. The equipment will represent the current state of the art and includes:

- a biogas test laboratory with continuously stirred tank reactors (CSTR) and batch test reactors.

- a gas chromatography laboratory for measuring organic acids and alcohols in the biogas process

- a laboratory for the determination of total organic Nitrogen (crude protein, XP), cellulose, hemicellulose and lignin (crude fibre, XF) and lipids (crude fat, XL)

- a laboratory for general analyses with drying technology, centrifuge and weighing technology

- a special area for sample preparation such as sorting and grinding

Examples of the respective equipment at the DBFZ are shown in Figure 2 to Figure 5. The container lab will be equipped accordingly.

The entire container building will be equipped with a central exhaust air system and de-ionised water will be provided by a central treatment plant at several tap points.

Figure 2: Lab reactors (CSTR) with 15 L working volume

Figure 3: Batch test system for automated determination of Biomethane potential

Figure 4: automated system for analysis of lipids (crude fat, XL)

Figure 5: system for automated disintegration to determine cellulose, hemicellulose and lignin (crude fiber, XF)

The biogas laboratory will contain essentially the same equipment as the biogas laboratory at the DBFZ site in Leipzig. Before the end of this year, a group of scientists and technicians from the University of Lomé will travel to Leipzig and receive comprehensive training and hands-on training at the biogas laboratory of the DBFZ. The aim of this training is not only to provide the colleagues from Togo with analytical training, but also to teach them basic maintenance and repair skills. The second part of the training will then take place in the completed laboratory building in Lomé. DBFZ scientists and technicians will then start up the laboratory together with their Togolese colleagues and support them in establishing the respective methods.

The planning of the container construction has been completed, all details of the furnishing and equipment have been specified. The layout of the entire container building is shown in Figure 6. The dimensions and dates for the preparation of the foundation and the necessary connections (electrical, water, sewage) have been determined.

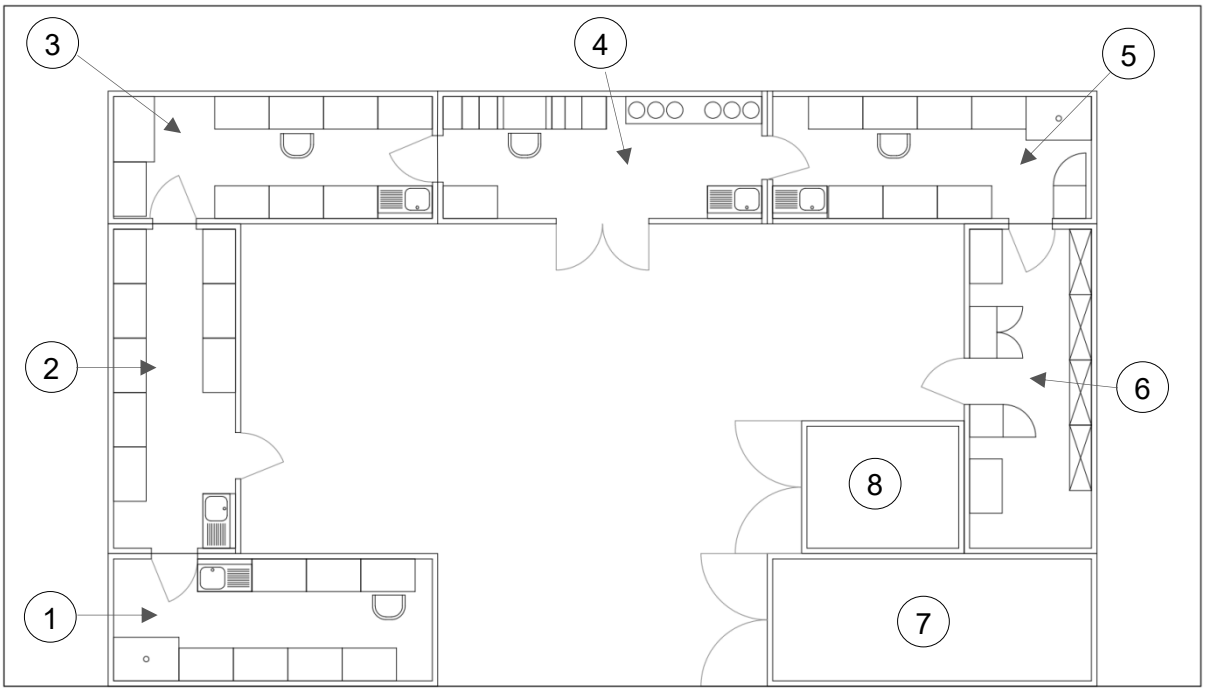

Figure 6: floor plan of the lab container building

1: lab for XF, XP, XF

2: sample preparation and milling are

3: lab with drying ovens, muffle furnace and general working area

4: Biogas lab with CSTR and Batch-Test-Systems

5: analytic lab witch GC-FID

6: store for chemicals, gas cylinders, samples / water purification unit

7: cold store (refrigerated container)

8: central energy hub

Work package 3: Studies on alternative methods for cooking stoves

Most of the people in Togo are currently still cooking with traditional open fire. This causes not only health problems due to the emissions but also a financial burden since the fuel has to be purchased in the form of wood or charcoal. In addition, direct use of wood is not sustainable considering the higher risks of deforestation and is therefore also problematic for ecological diversity and the climate.

In the meantime, a large number of stoves have been developed and used in field tests all over the world. Particularly in poorer regions, however, these are too expensive for the population due to the high selling price, depending on the type of the required material for the production (e.g. steel). Within the project, it is aimed to develop a low-cost and fuel-flexible stove which is easy to produce in the country and generates low emissions.

For this reason, a burner based on the use of liquid ceramic and with active ventilation is to be developed, which will be included in the existing pot holder of the usual used three-stone-fire. Although the use of active ventilation increases the costs, it is possible to enable lower emissions and better controlled combustion process. The extensive substitution of steel by ceramics should result in significantly lower production costs, which should compensate the use of active ventilation, so that a lower overall price can be achieved.

Since stoves with active ventilation require electricity, both a low-cost power control unit for the fan and the complete decentralized electrical infrastructure based on solar energy will be planned and tested on site.

Project status and first results

Project progress was significantly delayed in the first year, largely due to national and international constraints related to the COVID-19 pandemic. Despite these difficulties, progress was made in the crucial points of the individual work packages, which represent important building blocks for further successful project processing.

Outcomes of WP1

Figure 7 visualizes the methodological approach of change detection analysis, which is used for the identification of preference regions for biogas and pyrolysis activities. The detailed map shown in the upper circle exemplarily highlights areas exposed to large scale agricultural (red color) and urban (purple color) expansions.

First results of the change detection analysis between years 2001 and 2019 show, that extensive urban expansions especially appear around northern suburbs of the capital city Lomé. Nevertheless, smaller patches of urbanization can also be found in other regions. Newly established farmland can be detected in all regions with varying extents and is predominately established on woody areas and tree-savannas. Nevertheless, forests are degraded and converted to savannas and therefore, the expansion of arable land has to be regarded as a dominant driver for tree cover losses. The direct conversion of primary forests to agricultural areas cannot be detected at large scale.

Even though, global datasets derived from National Aeronautics and Space Administration (NASA) satellite imagery with international land cover classification schemes were used to identify relevant changes, the methodological approach of change detection analysis could also be repeated with locally explicit spatial information, if provided to the project, in order to enhance the level of detail.

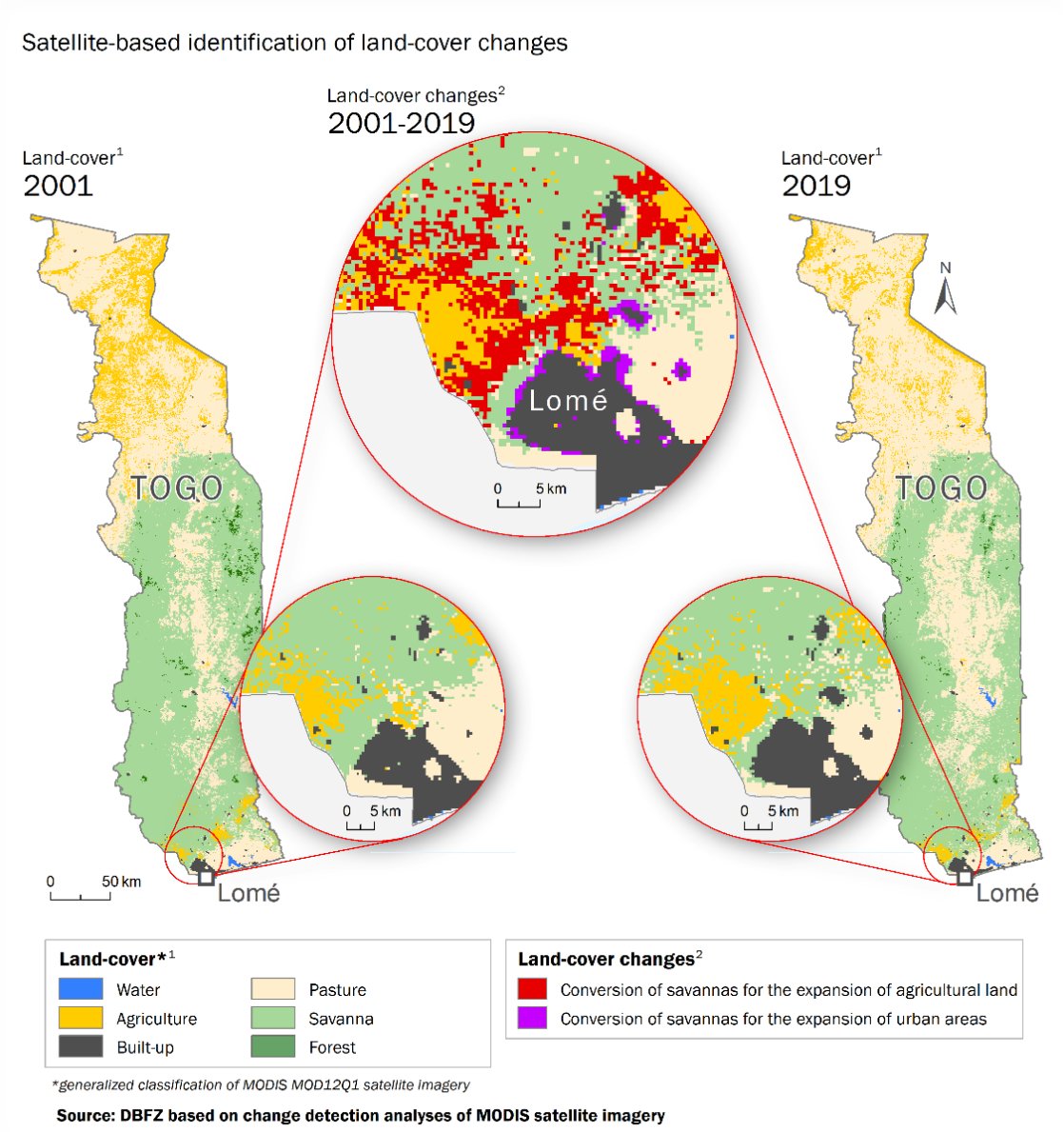

Figure 7 Simplified visualization of Change Detection analysis for the identification of preference region for biogas production

Outcomes of WP 2

The equipment for the laboratory has been specified in detail and the procurement process is underway. The first equipment has already been purchased and further devices will follw step by step. The initial commissioning of the laboratory equipment will take place in Leipzig. The equipment will be transported to Lomé in a refrigerated container once the entire equipment has been purchased. The refrigerated container will then remain in Lomé as part of the biogas laboratory (container No. 7 in Figure 6).

At the Université de Lomé, the granted site for the container Laboratory instalment is being prepared according to its specifications provided by the DBFZ. Main works done is the earth work and excavation including site clearance, leveling of the platform by removing soil layer with plant at a depth of at least 30 cm, backfill with laterite, backfill with crushed sand. The concrete and masonry and the remaining of the work to complete the site preparation will start before the end of March 2021 as the contractor selected provided detailed

documents which is submitted to the finance office for control before the go ahead of continuing.

Outcomes of WP3

So far, studies have been carried out about the production process with liquid ceramics and on the determination of the parameters for the combustion technology.

In the field of electronics and energy supply, the power control for the fan was developed and tested and the electrical infrastructure was planned.

Project outlook and summary

It is expected that substantial progress will be made in all three work packages this year. The field surveys, as shown in Table 1 and Table 2, have started and will provide extensive data for WP1. By including also biogenic waste, these data will also be important for further national strategic plans such as waste management concepts. As soon as the resource mapping delivers first results, the technology assessment for the identification of optimal utilisation strategies will be started. The main points of WP2 are to be completed before the end of 2021.

The execution of the container construction for the biogas lab has been put out to tender. It is expected that the contract will be awarded by mid-2021 and that the container construction will be completed in 2021. Transport to Togo and final assembly are planned for early 2022.

Later this year, a group of scientists and laboratory technicians from Togo will travel to Leipzig for a comprehensive training programme. The programme will include the methodology of various experimental and analytical investigations as well as a practical part including the maintenance and repair of laboratory equipment.

After the container construction in Lomé is completed, the second part of the training programme will be carried out there by scientists and laboratory technicians from Leipzig in the first half of 2022. Together with the Togolese colleagues, the complete commissioning of the laboratory will thus be carried out.

The prototype of the pyrolysis cooker will be tested and optimised in the coming months with real fuels, such as those available in Togo. The results of the field survey will also provide important data on the fuels used and their potential use. As soon as the final design has been determined, preparations for the production of the cookers in Togo will begin. Substantial progress is also expected here in the course of 2021.