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Wood Gasification in Uganda – Is this a solution for the Energy Crisis? Hard facts from installed units

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Abstract

There is urgent need to increase Uganda's electricity supply and more importantly reduce the country's dependence on the presently meager hydro electric power generation. Uganda is a growing economy with an average GDP growth rate estimated at 6.4% per annum. Economic growth is matched by growth in energy demands; fortunately we have a number of options at our disposal.

Of interest to the country is harnessing electricity from biomass. In small scale this can be done by gasification of the biomass. There are already some players in this sector of energy in Uganda. Musizi Tea Estate/James Finlay Uganda Limited has a 205 kW wood gasification unit. Yet another small unit belongs to Kasenge Electricity Power owned by a retired British civil engineer, Brian Frawley. A 10 kW unit generates electricity by wood gasification.

Nonetheless gasification is a complex process when compared with diesel genset electricity generation, maintenance is rather intensive. High level engineering and technical skills are require on a full time basis. This is lacking at the moment. In addition, the fuel supply chain has to be sustainable and it may require some added costs and organization, etc.

In an attempt to address these constraints CREEC, Centre for Research in Energy and Energy Conservation has developed a program to work with these pioneers to sustain the units and make viable the technology. It is also exploring alternative fuels such as agricultural residues.

This paper presents experiences from the use of gasification to meet small scale electricity generation using this technology and proposes some strategies for small scale gasification systems implementation.

Introduction

Walking along most streets in Kampala today, one is struck by the invariable whining sounds from small generators in merchandise shops – a reminder of the country's struggling economy and the fact that the energy sector is facing a severe shortage of electricity. Early in 2006, the government announced that hydroelectricity production at the two main power stations, Kiira and Nalubaale, would be reduced in a bid to check the water outflow from Lake Victoria. Thus, from an operating capacity of 380MW, there would be a mere 135 MW, for a national demand estimated at over 500MW. Today, looking back, there have been efforts to provide compensation for the low electricity output: thermal generators have been installed and there are plans to construct more hydropower stations along the Nile. There is also renewed interest in energy saving techniques, as well as renewable energies. Among the latter is gasification of biomass.

Gasification is a waste-to-energy process that involves converting biomass into a combustible gas that may for instrance be used as a substitute for petroleum fuels to generator sets. The technology is well known but there is almost no capacity in Uganda for utilisation of it for local electricity generation. The recently installed 205 kW unit at a tea estate and 10 kW unit at Mukono in combination with the research capacity being developed at Makerere University with support from Sida/SAREC in Sweden could be utilised as a basis for development of a gasification industry in Uganda.

The possibilities for this are discussed in this paper.

The Process of Gasification

Simply put, gasification is a conversion of solid fuels into a combustible gas. The process was originally developed in the 1800s to produce town gas for lighting and cooking. Natural gas and electricity soon replaced town gas for these applications, but the gasification process has been utilized for the production of synthetic chemicals and fuels since the 1920s. Wood-gas generators, called *gasogene* or *gazogène*, were used to power motor vehicles in Europe during World War II fuel shortages [1]. The increasing petroleum prices in the 1970:s lead to an interest in using gasification for fuelling of engines used in different applications in developing countries. Many of the "demonstration projects" failed because the suppliers of equipment lacked the necessary experience, because the local infrastructure could not support the technology or because the users were not prepared for the additional maintenance and service efforts required.

Essentially, the process of biomass gasification converts the carbon, hydrogen and oxygen in the cellulose, hemi-cellulose and lignin that constitute biomass into a mixture of carbon monoxide, hydrogen, methane, carbon dioxide, water vapour and small amounts of more complex organic species. The process requires a temperature exceeding about 1000^{o}C and the high temperature is achieved by partial combustion of the biomass either with pure oxygen or with air. In the latter case, the product gas will be diluted with nitrogen.

Oxygen gasification, often at elevated pressure, is used as part of some processes for production of liquid petroleum substitutes from biomass. It requires sophisticated technology and will only be economic at large scale. Gasification with air can be achieved in relatively simple gas producers operating at close to atmospheric pressure or a slight vacuum. There are numerous examples of gas producers successfully manufactured in developing countries, also in Africa.

The flow scheme shown in figure 1, illustrates the main process steps used in a gasifier installation for generation of electricity with an engine generator set.

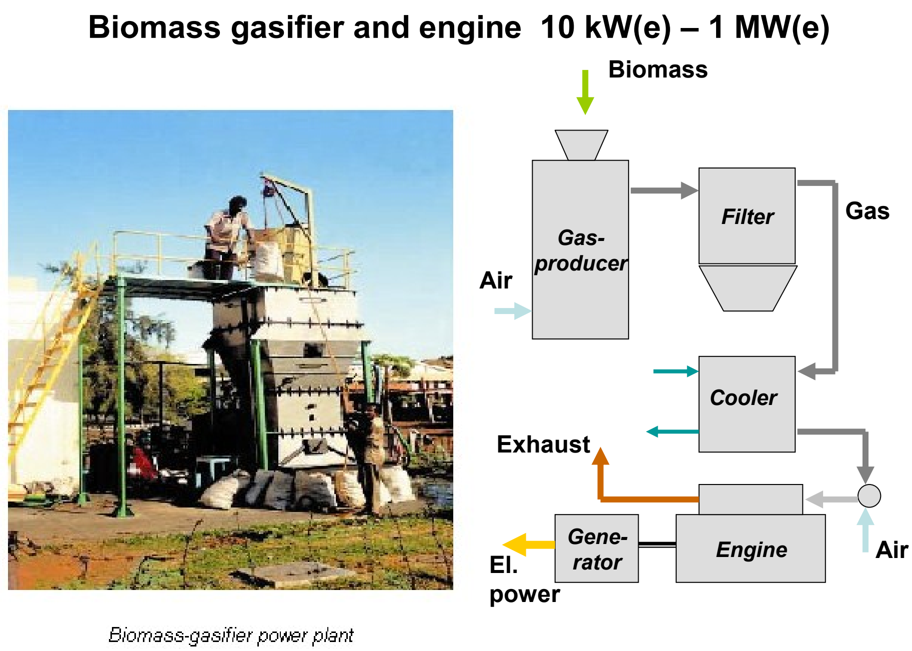

Figure 1. Generator set operated with a biomass gasifier

In its simplest form, the gas producer is fuelled manually by the operator. Typically fuel must be added once or twice per hour. The air used for gasification is sucked into the gas producer by the engine, which leads to a slight vacuum in the entire system. The product gas, often called gengas or producer gas, is filtered to remove dust, cooled to reduce water vapour and tars and increase the energy content per unit volume. After the cooler, the gas has a heating value of about 5 MJ/m^3 and consists typically of 18% CO, 17% H_2, 2% CH_4, 12% CO_2 and 7% H_2O. The balance is mainly N_2.

There are different designs used for the gas producer. For fuelling of engines the so called downdraft gas producer with a throat, see figure 2 are often preferred because it will deliver a gas with a low tar content if properly designed and operated. Tar in the gas can lead to serious operational problems because it can deposit in the inlet manifold and in inlet valve guides. Proper matching of gas producer design and fuel properties is very important. Failure to do so will inevitably lead to operational problems. Chunky fuels with particle size of a few cm and a moisture content below 20% are ideal. Wood blocks, cut maice cobs and crushed coconut shell are examples of this. Loose and light fuels represented by many agricultural residues may be briquetted to be suitable in downdraft gas producers with a throat but may also be used directly in other types of gas producers that generate a gas with a higher tar content. A separate process step for tar removal from the gas will then often be necessary.

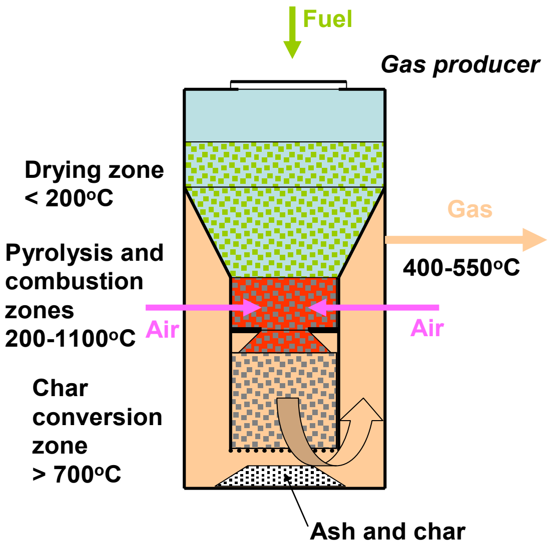

Figure 2. Principle of downdraft gas producer with throat

There is an increasing interest in the industrialised part of the world in using more advanced biomass gasification processes as part of processes for production of liquid fuel substitutes. These processes might also be of interest in Uganda but in the short term, the simple gasification process is probably a quicker route to expanded small scale electricity generation based on indigenous fuels. By proper design of the components of the system it should be possible to manufacture all the components in a gasifier system with materials that are already available in Uganda. Engines and generators will still have to be imported, but these are standard products that are commercially available from many suppliers.

The high content of CO in the groducer gas involves health hazards. Operation of the system at a slight vacuum reduces the risk for exposure of the operators to CO, but refuelling and other service tasks must follow proper procedures to minimise the hazards.

Sustainable Biomass Supply
An economically viable gasification system for electricity production requires a sustainable feedstock supply. On-farm trees and agricultural residues may not be sufficient. Table 1 presents estimates for the wood consumption and area demand per kW installed, as well as the percentage electrical efficiency and stand productivity. In the best or least land-consuming case, one would still have to calculate with 0.3 ha per kW installed if the average load is 50% of the installed capacity. If agricultural residues are available without drawbacks on soil fertility, the required area will be smaller [6].

Table 1: Area demand per kW at 50 % load factor for different efficiencies and growth rates

	Wood Consumption in kg/kWh	Percentage Electrical Efficiency	Annual Stand Productivity in dry tons	Area Demand in ha/kW
'Worst' Case	1.5	13 %	5	1.3
'Best' Case	1.0	20 %	15	0.3

East Africa has a high potential for energy biomass production, with large amounts of land that could be used to produce sustainable yields with Short Rotation Coppice (SRC) systems on steep slopes, degraded land or agricultural fallows. SRC systems have dense tree or shrub plantations that are harvested at 1-4 year intervals. They re-sprout after harvest (coppice), while maintaining a high productivity such as the native *Markhamia lutea*, or Eucalyptus ssp. These systems contribute to soil conservation, biodiversity and carbon sequestration. Nitrogen-fixing species, such as Acacia ssp. or the native *Sesbania sesban*, enhance soil fertility over the long run and build up organic matter.

Owing to the rapidly decreasing natural forests, it is recommended that wastes be preferred to wood, as a biomass feedstock for the gasification system. Organic wastes are an important, locally available energy source, since almost all human activity indirectly contributes to their increase, specially in form of agricultural residues [6]. Agricultural residues are the leftovers after crops are harvested or processed. Currently most of these residues are left unused, burnt in the fields and on a small scale used for space heating in rural areas as well as for commercial use in few thermal industrial applications [6]. The use of these agricultural residues for industrial purposes is much more environmentally friendly practice than many residue disposal methods currently in use.

Agricultural residues are an excellent alternative to using woody biomass for many reasons. Aside from their abundance and renewability, using agricultural residues will benefit farmers, industry and human health and the environment [7]. Adaptation of the gas producer design for trouble-free operation on some agricultural residues is still a challenge, however.

Potential Benefits of Gasification Technology

Generally, many regions would like to see an increased deployment of such environment-friendly technologies as gasification because of their perceived socio-economic benefits.

Provision of affordable power

In the communities where electrification projects have been set up, there has usually been a provision of subsidies such that more people could afford it. In most of Uganda, which is rural, the connection to the national electricity grid is unaffordable or impossible and so such local projects would extend accessibility to energy at the grassroots of society.

Creation of employment opportunities

The setting up of gasification projects in rural or urban communities would provide jobs for many, especially since more unskilled than skilled labor would be required. Each project could be organized with the collaboration of the local community, such that they eventually take over its running.

Contribution to economic growth

Provision of affordable energy is a prerequisite for economic development, since most modern economic activities employ such energy. The economy benefits directly through business expansion and employment and import substitution, which has direct and indirect effects on the GDP and trade balance [4].

Recent Experiences from Gasification in Uganda

There are already some players in this sector of energy in Uganda. Musizi Tea Estate/James Finlay Uganda Limited has a 205 kW wood gasification unit. Yet another small unit belongs to Kasenge Electricity Power owned by a retired British civil engineer, Brian Frawley. A 10 kW unit generates electricity by wood gasification.

Musizi Tea Estate commissioned its unit in 2005. 1000 cubic centimeter Eucalyptus billets are dried for 6 months before they are gasified to generate up to a present maximum of 150 kW of the estates electricity demands. The gasifier uses 1.6 kg of wood and diesel worth US$ 0.25 to generate a kWh of power. The generation plant is operated by one full time engineer and 11 other employees for 12 hours daily and 6 days a week.

Overall an investment of 2.087 US$/kW was made and the gasifier is maintained weekly. Nonetheess, the Internal Rate of Return (IRR) for the project is reported as 30% which is very good and theoretically would make gasification a profitable business.

Another gasification project is a the small unit belonging to Brian Frawley's Kasenge project uses 5 square centimeter Eucalyptus prunings that have been dried for 3 months. The dry wood is fed into an electric saw-bench that cuts it into pellets; these are then collected and poured into a gas retort and covered (the retort must be cleaned daily). There is a mainstream motor started by a battery, a three-phase switch board is turned on and within 10 minutes, electricity is generated. 15 kilograms of wood and 1 litre of diesel are needed to generate 1 kWh of electricity. The unit operates for 17 hours daily and requires 1.5 hours of maintenance daily.

The scheme produces 6 kVA in excess of his farms requirements of 2 kVA, no move has however been made to sell off the excess power generated to Umeme. Frawley bought 30 electricity poles and 700 meters of electric wires at a total cost of Ushs 3.1m to transmit the power to his house, pig sty and security lights on his 240 hectare farm.

These private sector players find it difficult to handle their gasifiers as there are no experts in the market to give consultancy on fuel supply, calibration, repairs, etc. Makerere University Faculty of Technology, CREEC hopes to be able to avail all this plus create capacity for designing, fabricating, repairing and maintaining those units and also training more technicians to make gasification a safe and efficient source of energy for Uganda.

So far we have already achieved the following:

Verified reasonable availability of non-woody residues in Uganda including: coffee husks, rice husks, bagasse, sawdust, groundnut shells, cow dung, maize cobs, cotton stalk, palm seed trash and sorghum stalk
Gasifier designed, constructed and now at Makerere. It is a multifunctional unit (combines updraft and downdraft modes) and allows use of a variety of fuels.
Test with pellets as fuel gave encouraging results:
25% combustible products in the gas produced
4.5 MJ/m2 Heating value of the gas
Temperature of burning gas reached 1240oC which is capable of firing a ceramic furnace
Suitability of different nonwoody biomass sources evaluated
Simulation of an indirect micro-turbine system for generation of electricity carried out

Constraints

Considering gasification as a new concept in Uganda means that there will be some measure of opposition to its rapid deployment. In addition, the technology has its own associated drawbacks.
Limited awareness
As a new technology, gasification requires first to be accepted by prospective customers, who, with limited knowledge and experience with it, may prefer to use well established technologies that are perceived to be less risky. The process of increasing awareness is often slow, requiring that customers be convinced almost one at a time. According to some authors, one of the main obstacles to the expansion and acceptance of bioenergy into world markets is that the markets do not acknowledge the real costs and risks associated with the use of fossil fuels [4].
Lack of local equipment suppliers and service infrastructure
The experiences from the early 1980:s when companies in industrialised countries installed demonstration plants that generally failed in developing countries indicate that a local infrastructure for maintenance and service must be available if the technology shall survive and find widespread use [8].
Lack of proven gas producer designs for some agricultural residues
In particular loose and light residues with high ash content will lead to operational problems in standard designs of downdraft gas producers with a throat. Various approaches are possible but the issue requires further research for adaptation of designs to the residues that are locally available.
Installation and operation cost
Most bioenergy technologies have higher purchase and installation costs than conventional technologies [4]. Also the operation will often require additional personnel. This will be compensated by a lower fuel price, but in particular the additional initial investment can be a serious obstacle to introduction of such technologies.
Complexity and maintenance requirements
Operation of a generator set with a gas producer is more complicated than if liquid fuel is used. Fuel preparation and handling is more cumbersome. Safe operation requires that strict procedures for re-fuelling and other service tasks are followed. Frequent cleaning of filters and monitoring of the condition of the different process components is necessary for trouble-free operation.

The way forward for Uganda

The specific objectives for the future are:

Verify the availability and sustainability of supply of non-woody biomass resources in the country.
Identify the potential uses and users of energy derived from non-woody biomass.
Carry out experimental tests to establish the physical and chemical properties of the non-woody biomass samples that are available.
Develop a working/tested multi-fuel gasifier for use under the Ugandan situation.
Demonstrate the capability of a gasifier fed with non-woody biomass to meet industrial-type process heat and electricity generation requirements.
Build capacity for fabricating units in Uganda with the support of Sida/SAREC and the Private Sector Foundation (U).

References

www.answers.com, August, 2007.
http://www.answers.com/topic/reactor-jpg (Accessed on 6th August, 2007, at 1015 hrs).
2004 World Survey Results of the Current Gasification Industry Perspective. U.S. Department of Energy, Office of Fossil Energy and National Energy Technology Laboratory. (http://www.netl.doe.gov/publications/brochures/pdfs/**Gasification**_Brochure.pdf, Accessed on 27th July, 2007, at 1005 hrs).
Domac, J., Richards, K., Segon, V. Old Fuel for Modern Times; Socio-economic drivers and impacts of bioenergy use, Renewable Energy World. Review Issue 2005-2006, July-August 2005 Volume 8 Number 4, Pg 114.
Karekezi, S., Ranja, T. Renewable Energy Technologies in Africa. African Energy Policy Research Network-AFREPREN. Bookcraft, Bath, UK, 2002, Pg 44.
Buchholz, T., Volk, T., Tennigkeit, T., Da Silva, I.P. Economics of a Gasification-based Minigrid – a case study from a 10kW unit in Uganda. Domestic Use of Energy Conference. 2007.
M. Okure, J.A. Ndemere, S.B. Kucel, B.O. Kjellstrom Suitability Of Agricultural Residues As Feedstock For Fixed Bed Gasifiers – International Conference in Engineering Solution – Entebbe – Uganda, July 2006.
Knoef H A M Handbook Biomass Gasification, BTG biomass technology group, Enschede, The Netherlands, 2005