ECONOMICS OF A GASIFICATION BASED MINIGRID – A CASE STUDY FROM A 10 KW UNIT IN UGANDA

Thomas Buchholz[a], Timothy Volk[a], Timm Tennigkeit[b], Izael Da Silva[c]
[a]State University of New York, College of Environmental Sciences and Forestry (SUNY-ESF), USA, [b]UNIQUE-forestry consultants, Germany, [c]Centre for Research in Energy and Energy Efficiency (CREEC), Uganda

ABSTRACT

Small-scale wood gasification systems have the potential to contribute to the rural electrification in Uganda. This paper presents an economic analysis of a 10 kW gasifier unit and its minigrid installed on a Ugandan farm. The bioenergy system has been running stable on a six hour daily base for seven months. When the gasifier is operated close to the rated capacity, the gasifier system is economically attractive compared to diesel generated electricity Results indicate that replicating successful wood gasification systems stipulates integration of sustainable fuelwood supply and viable business models.

Keywords: small-scale gasification, economic analysis, business models, sustainable fuelwood supply

1. INTRODUCTION

Access to modern energy, such as electricity, is crucial in order to achieve the Millennium Development Goals of poverty reduction, improved education, and environmental sustainability [1]. Without modern energy services, development beyond a certain level is virtually impossible. Currently about one third of the world's population, or two billion people, have only intermittent access to modern energy services. Another third – largely consisting of the rural poor – have no access to modern energy services at all. The latter group will swell in the years ahead unless steps are taken now to change this pattern. Sub-Saharan Africa, in particular, has the world's highest rural population growth rates but is dramatically behind other regions of the world in rural electrification. Access to basic modern energy services in rural areas tends to be neglected due to the urban bias of political and administrative power. For example, in Uganda, about 84% of households are located in rural areas but less than 1% of them have access to modern energy services [2].

People without access to modern energy services rely on increasingly scarce traditional biomass sources and inefficient, polluting conversion systems, such as traditional cookstoves. Women and children inhale deadly indoor fumes while cooking [3] and spend considerable amounts of their productive time collecting dwindling and distant supplies of wood. A lack of access to modern energy services results in a lower quality of life, limited opportunities for economic development, and environmental degradation. Surprisingly, the absence of basic modern energy services is not necessarily a result of financial poverty. Many poor already pay more per unit of energy than the better off due to inefficient technology and corruption [4].

Proven small-scale conversion technology like gasification can be operated by minimally trained local community members and provides efficient and CO2 neutral energy at the local level [5, 6]. Such power systems can run enterprises that are aiming to add value to agricultural products such as grain mills or drying or cooling chambers, run machinery for local manufacturing, improve local health services by refrigeration of vaccines, enable access to communication and information technologies, and increase daily productive hours by providing light in houses and commercial and public buildings. Creating successful bioenergy systems using local structures would lower reliance on energy imports, increase community self-reliance, improve the quality of life and environmental conditions at both a local and global level.

Despite encouraging biomass growth conditions, modern bioenergy systems have been neglected in Uganda. In Uganda, increased demand and rising fossil fuel prices have caused the grid electricity supply to deteriorate, and even in the capital power cuts are common now. Unreliable electricity services forces industries to invest an estimated 34% of total investment into generators as backup systems [7].

2. ELECTRICITY FROM SMALL-SCALE GASIFICATION IN UGANDA – A CASE STUDY

There is now increasing regional interest in exploring the potential for distributed bioenergy systems from both the national authorities for rural electrification and private agro businesses. Bio-energy systems are in various assessment and installation stages. This paper highlights operational aspects and financial implications of a 10 kW gasifier system that has been installed on a 100 acre farm in Mukono, Uganda.

2.1 TECHNICAL ASPECTS

The gasifier installed is manufactured by Ankur Scientific India and powers a Fieldmarshall modified diesel engine that runs on a dual fuel-mode rated at 25 % diesel and 75 % gas producing 3-phase electricity. The maximum electrical output is rated at 10 kW. Due to the small size and the capability of the engine to start with 100 % diesel it can be stated off a battery and does not need an additional generator to start. The vacuum created by the air intake of the engine is enough to run the gasifier without the need for an additional blower. Once the gas is produced, the diesel share of the fuel is reduced automatically governed by the engine speed. Starting time is between 5 to 10 minutes.

The gasification system has a footprint of 4 x 4 m with another 10 x 4 m shed attached for storage and processing of the fuel (figures 1 and 2).

Figure 1: Gasifier shed with fuelwood storage and precessing shed attached.

Figure 2: 10 kW dual fuel mode gasifier for electricity production.

The grid consists of 30 electricity poles and a total of 700m wire to transmit power to the farm house, pig stay and security lights.

2.2 OPERATIONAL ASPECTS

The gasification system has been running since August 2006 on a daily basis for 6 hours in the evenings producing 3kW on one phase only. It is fueled by eucalyptus prunings from the farm with diameters of less than 2cm and which are cut by a circular saw to a maximum length of 5cm and air dried for 3 months. The system is operated by an employee with a three years college course in electrical installations, daily workload is approximately 1.5h per day including fuel preparation. The 500 litres of cooling water are replaced every 2 to 3 months.

2.3 EFFICIENCY AND FINANCIAL ANALYSIS

2.3.1 Scenario 1: Current situation

Under the current use of 18kWh daily, the gasification system uses 0.84kg of air dried wood and 0.17 litres diesel per kWh produced. This sums up to 15 kg of wood and 3 litres of diesel per day. As seen in Table 1 last column, the dual fuel mode ratio diesel to woodfuel is close to 1:1 and not 1:3 as rated by the manufacturer. This implies that only 3 litres of diesel are saved every day. Under this scenario, even when excluding labor and fuelwood costs, the system produces electricity at 0.67 $/kWh and is not competitive with diesel gensets (for capital costs, grid costs, diesel costs etc. in this calculation, refer to table 2).

Table 1: Energy shares between the two fuels in dualfuel mode at 3 kW.

	CON-SUMPTION	ENERGY CONTENT	CON-VERSION EFFICIENCY	TOTAL SHARE PER KWH$_{ELEC}$ PRODUCED
Diesel	0.17 l/kwh	3 kWh	33 %	50 %
Fuel-wood	0.84 kg*/kWh	4.25 kWh*	14 %	50 %

2.3.2 Scenario 2: Increased power demand

The high diesel share of 50 % of the total energy required for electricity production in scenario one is caused by the little power demand. Running the system close to its rated capacity of 10kW would allow to shift the fuel ratio towards a higher fuelwood share and decrease relative fuel costs. At the same time, a higher power output would decrease capital costs per kWh produced.

It is obvious that at this low baseload the gasification system can not operate efficiently In scenario 2 it is assumed that the same gasification system is running at 9 kW (e.g. not only supplying the farm but also the neighbouring village) for 12 hours a day. This is still a fairly conservative scenario as the maximum rated capacity is not used and the system runs only half of the day. Table 2 shows operation costs and input assumptions as well as the economic implications.

Table 2: Input and output figures for the gasifier system producing 9 kw for 12 hours a day.

COST AND INPUT ASSUMPTIONS		
Fuelwood price	18.5	US$/ton*
Diesel price	0.96	US $/1
Diesel share in fuel mix	25%	%
Electricity output	9kW	kW
Load factor	50%	%
Electricity costs (diesel genset)	0.35	US $ kwh
Interest rate %	10%	%
Depriciation period	10	yrs
OUTPUT		
Net Present Value (NPV)	32,508	US$
Internal Rate of Return (IRR)	51%	%
Investment costs	2,300	$/kW
Electricity costs	0.20	$/kWh
Fuel costs (diesel and wood)	0.10	$/kWh
Fuelwood supply	136	Kg/day
Diesel supply	8.9	l/day

Under technical and financial aspects, scenario 2 is economically viable and an attractive alternative to a diesel generator. It produces electricity at 0.2 US$/kWh and earns an IRR of 51 % considering a electricity price for diesel generated power of 0.35 $/kWh. As can be seen in figure 3, the highest share of total costs, of over 50 %, are the capital costs. However, this high up-front investment can be justified by the low running costs, i.e. fuel costs of 0.1 $/kWh. Labour costs to operate the system – which are often used to argue against gasification when compared with diesel fueled power production – account for 5 % of total costs only. The payback period is less than three years (see figure 4).

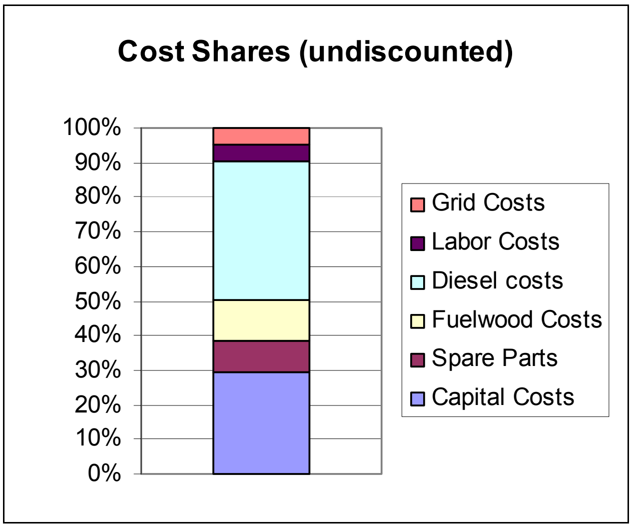


Figure 3: Relative production costs for scenario 2: 9 kW production over 12 hours each day

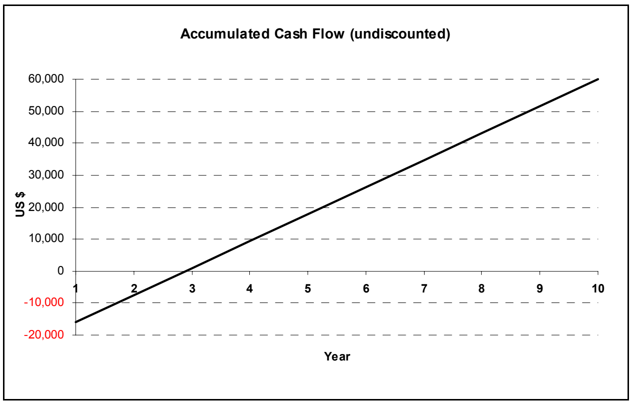


Figure 4: Payback period for scenario 2

3 IMPLICATIONS OF ELECTRICITY FROM GASIFICATION

3.1 SUSTAINABLE FUELWOOD SUPPLY

An economically viable gasification system for electricity production (see scenario 2) requires a sustainable feedstock supply system. On-farm trees and agricultural residues are usually not sufficient.

In table 3 the minimum and maximum area demand for the feedstock is presented per kW installed. In the best or least land-consuming case, one would still have to calculate with 0.5 ha per kW installed. If agricultural residues are available without drawbacks on soil fertility this will reduce the required area.

Table 3: Area demand per kW at 80 % load for different efficiencies and growth rates.

	CONSUMPTION IN KG WOOD/KWH	ELECTRICAL EFFICIENCY IN %	STAND PRODUCTIVITY IN TONS	AREA DEMAND IN HA/KW
'Worst' Case	1.5	13 %	5	2.1
'Best' Case	1.0	20 %	15	0.5

East Africa has one of the greatest potentials for energy biomass production in the world [8]. The region has large amounts of land that are too marginal for food crop production, but could produce sustainable yields with Short Rotation Coppice (SRC) systems on steep slopes, degraded land or agricultural fallows [9]. SRC systems consist of densely planted trees or shrubs that are harvested at 1-4 year intervals and resprout after harvest (coppice) while maintaining a high productivity such as the native *Markhamia lutea*, or Eucalyptus ssp. SRC systems produce many environmental and rural development benefits like soil conservation, biodiversity enhancement and carbon sequestration [10, 11, 12, 13]. Nitrogen fixing species such as Acacia ssp. Or the native *Sesbania sesban* enhance soil fertility over the long run and build up organic matter. Only if biomass is sustainably produced, wood gasification systems will reduce the pressure on natural forests.

3.2 VIABLE BUSINESS MODELS FOR ENERGY SERVICES

The 10 kW case study from Uganda clearly shows the need for well designed business models to manage the feedstock supply, conversion technology, and energy allocation. Such business models have to provide incentives for farmers and entrepreneurs to provide biomass and electricity all year around. Energy Service Companies (ESCOs, [14]) do not exist yet in Uganda but lessons learned from other developing countries [15, 16] can be considered in the design. Nevertheless without reliable business models investors will not take the risk to invest in respective systems. Therefore, public private research and capacity building is required to develop and promote respective business opportunities and to overcome existing barriers such as the high capital costs for gasifier systems.

4. CONCLUSIONS

Recent studies demonstrate the economic viability of bio-energy, stressing the need for innovative market and investment schemes in Uganda [17].

As yet, there are very few bio-energy projects that have been broader in scope than the sole implementation of conversion technology in the developing world, and none of these projects have targeted East African communities in particular. The 10 kW gasifier project analysed in this paper – which is the first of its kind in Uganda – proves that this system is technically proven, efficient, and economically viable when put in the right setting. Operational constraints like a sustainable biomass supply and energy allocation have to be urgently addressed and business models need to be developed.

The three components of bio-energy - feedstock supply, conversion technology and energy allocation - need to be integrated to effect change [18].

5. REFERENCES

[1] Modi, V., McDade, S., Lallement, D., Saghir, J. 2006. Energy and the Millenium Development Goals. Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project, and World Bank.

[2] MWLE (2001). Capacity building in clean development mechanism in Uganda. The ministry of water, lands and environment, department of meteorology. 02.15.2006 <http://uneprisoe.org/CDM/CDMCapacityBuildUganda.pdf>

[3] Bailis, R., Ezzati, M. & Kammen, D. M. (2005). Mortality and greenhouse gas impacts of biomass and petroleum energy futures in Africa. Science, 308(5718), 98-103.

[4] DFID. (2002). ENERGY FOR THE POOR - Underpinning the Millennium Development Goals. Department

[5] Nouni, M.R., Mullick, S.C., Kandpal, T.C. 2007. Biomass gasifier projects for decentralized power supply in India: A financial evaluation. Energy Policy, 35: 1373-1385.

[6] Ravindranath, N. H., Somashek, H. I., Dasappa S., Jaysheela Reddy C. N. (2004). Sustainable biomass power for rural India: Case study of biomass gasifier for village electrification. Current Science, Vol. 87, No. 7.

[7] Eberhardt, A., Clark, A., Wamukonya, N., Gratwick, K., (2005). Power Sector Reform in Africa: Assessing the impact on poor people. World Bank Energy Sector Management Assistance Program. Washington D.C., 198 p.

[8] Hoogwijk, M., Faaij, A. x. e., Eickhout, B., de Vries, B. & Turkenburg, W. 2005. Potential of biomass energy out to 2100, for four IPCC SRES land-use scenarios. Biomass and Bioenergy, 29(4), 225-257.

[9] Siriri D., Raussen T. 2003. The agronomic and economic potential of tree fallows on scoured terrace benches in the humid highlands of Southwestern Uganda. Agriculture Ecosystems and Environment 95 :359–369.

[10] Volk, T.A., Verwijst, T., Tharakan, P.J., Abrahamson, L.P. 2004. Growing Energy: Assessing the Sustainability of Willow Short-Rotation Woody Crops. Frontiers in Ecology and the Environment. 2(8):411-418.

[11] Heller, M. C., Keoleian, G. A., Volk, T. A. 2003. Life cycle assessment of a willow bioenergy cropping system. Biomass Bioenerg. 25: 147-165.

[12] Tolbert, V. R., Todd Jr., D. E., Mann, L. K., Jawdy, C. M., Mays, D. A., Malik, R., Bandaranayake, W., Houston, A., Tyler, D., Pettry, D. E. 2002. Changes in soil quality and below-ground carbon storage with conversion of traditional agricultural crop lands to bioenergy crop production. Environ. Pollut. 116: 97-106.

[13] Aronsson, P. G., Bergstrom, L. F., Elowson, S. N. E. 2000. Long-term influence of intensively cultured short-rotation Willow Coppice on nitrogen concentrations in groundwater. J. Environ. Manage. 58: 135-145.

[14] Vine, E. 2005. An international survey of the energy service company (ESCO) industry. Energy Policy,Volume 33, Issue 5: 691-704.

[15] Ellegård, A., Arvidson, A., Nordström, M., Kalumiana, O.S., Mwanza, C. 2004. Rural people pay for solar: experiences from the Zambia PV-ESCO project. Renewable Energy, Volume 29, Issue 8: 1251-1263.

[16] Lee, M.K., Park, H., Noh J., Painuly, J.P. 2003. Promoting energy efficiency financing and ESCOs in developing countries: experiences from Korean ESCO business. Journal of Cleaner Production, Volume 11, Issue 6: 651-657.

[17] Tennigkeit, T., Kallweit, K., Buchholz, T. (2006). Decentralised rural electricity production from energy

forests - Investigating the feasibility of business models for a demonstration project. Report to the Sawlog Production Grant Scheme (SPGS), EU Forest Resource Management and Conservation Programme Uganda. Kampala, Uganda, 36 p.

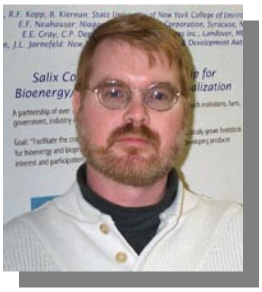
[18] Buchholz, T., Volk, T., Luzadis, V.A. 2006 in press. A participatory systems approach to modeling social, economic, and ecological components of bioenergy. Energy Policy

6. AUTHORS

Principal Author: Thomas Buchholz holds a M.Sc. degree in forest sciences from Freiburg University, Germany. He is currently pursuing a PhD on bioenergy at the State University of New York, College of Environmental Sciences and Forestry.

Address of author:

Thomas Buchholz, State University of New York, College of Environmental Sciences and Forestry (SUNY-ESF), Illick Hall 340, 1 Forestry Drive, Syracuse NY 13210, USA, phone: +1 315 470 6775, fax: +1 315 470 6934, email: tsbuchho@syr.edu



Co-authors: Dr. Timothy Volk is a research associate at SUNY-ESF, is a leading researcher on SRC and has been working on SRC and agroforestry systems for over 15 years. He is in charge of the Salix Consortium, a unique approach that brings together producers and consumers of SRC products to facilitate the commercialization of these systems in North America. He has several years of direct experience on community based forest management and agro-forestry systems in Africa.

Dr. Timm Tennigkeit is a Director of FIS with more than 10 years of research, teaching and practical experiences in bioenergy, silviculture and plantation forestry. He has a proven track record in environmental impact assessment and the development of markets for environmental services. He has coordinated regional research programmes on forest restoration and management. Currently he is the country manager of ENCOFOR (Environment and community based framework for designing afforestation, reforestation and revegetation projects under UNFCCC rules).

Dr. Izael Pereira Da Silva holds a PhD in Power Systems Engineering from the University of Sao Paulo (Brazil). He is also a Certified Energy Manager. At present he is a Senior Lecturer at Makerere University, and the Director of Centre for Research in Energy and Energy Conservation, CREEC.

Presenter: The paper is presented by Al-Mas Sendegeya.