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Domestic Biogas as a Driving Factor of Sustainable Development in Mugunga Sector of Gakenke District, Northern Rwanda

Maniriho, Aristide[1] and Uwimana, Robert[2]

[1]Department of Applied Economics, Institut d'Enseignement Supérieur de Ruhengeri (INES-Ruhengeri), P. O. Box 155 Ruhengeri, Rwanda.
Email: *manirihoaristide1@gmail.com* (Corresponding author)

[2]Department of Applied Economics, Institut d'Enseignement Supérieur de Ruhengeri (INES-Ruhengeri), P. O. Box 155 Ruhengeri, Rwanda.
Email: *robertuwimana@yahoo.fr*

Abstract

This research focused on domestic biogas as a key driver of sustainable development in Rwanda, with special reference to Mugunga Sector of Gakenke District, Northern Rwanda. Data were collected from a sample of the heads of all households operating domestic biogas plants in the study area to whom a well structured questionnaire were administered in July 2013. Data were analyzed referring to the frequency counts, percentages. Besides, the NPV method was used to analyze the profitability of domestic biogas investment. The results indicated that domestic biogas contributes to the improvement of social conditions of households in the study area. It also has positive economic effects as well as contributes to the environmental protection. Socially, some respondents (80%) reported to use the domestic biogas for cooking everyday whereas some others (20%) say that domestic biogas is used rarely in cooking. The calculations of the net present value for domestic biogas investment without government subsidies (given the total investment cost of FRW 417,500 considers the present value of total revenue of FRW 459,078 and the present value of the total cost of FRW 523,099. The net present value without government subsidies is then -64 901. As a result, there is a loss from investing in domestic biogas plant without government subsidies. In contrast, the investment in domestic biogas with government subsidies is profitable as the corresponding net present value is 68,697. It is recommended to the households operating the domestic biogas plants to use it optimally and to the local authorities to sensitize farmers with enough cattle to invest in domestic biogas.

Key words: domestic biogas, driving factor, sustainable development, Mugunga Sector, Gakenke District, Northern Rwanda

1. Introduction

Rwanda is the most densely populated country in Africa, landlocked with few natural resources and minimal industry and it depends heavily on its natural resources, namely land, forests, water and wildlife [1]. These resources constitute the country's main sources of households and national income, providing the basis for farming, fishing, household energy production as well as tourism [2]. As in most developing countries, Rwanda relies upon wood fuels, which account for at least 86% of energy consumption.

According to Dekelver et al. [1], this coupled resulting in an over exploitation of wood plantation and forestry, which is intensifying as the population grows and causing environmental degradation. There are many problems associated with deforestation: flooding, siltation, loss of plants and animals, genetic material that have great potential value for medicine, agriculture and other industries. To handle this issue of deforestation, many developing countries like Rwanda replace traditional energy source by domestic biogas use. Socially spoken, livestock keepers are active members of and well represented in associations and there are no restrictions for women to be involved in domestic decision making and the operation of biogas plants.

Rwanda is the most densely populated country in Africa [3], landlocked with few natural resources and minimal industry.

Corresponding Author: Maniriho, Aristide

Respiratory illnesses come second after malaria in terms of causes of morbidity in health facilities. The majority of households own two or more cattle, used for milk, meat and dung production and for financial security. Legislation is in place that prohibits free roaming of cattle. Almost all cattle are kept in stables overnight, while a growing part is kept on zero-grazing. At farms where stabling is practiced, farmers have access to water. The quality of the arable land is mostly poor due to the high cultivation intensity. Due to the consequent need for fertilizers, the composting of dung is commonly practiced to maintain or improve the soil fertility. The climatic conditions in Rwanda are favorable to operate biogas plants all year round [4].

Like other developing countries, Rwanda needs to achieve sustainable development. In this way, the Government of Rwanda is undertaking various policy actions aiming at poverty reduction. These policy actions include the Economic Development and Poverty Reduction Strategy (EDPRS), Environmental Protection Policy, National Domestic Biogas Programme (NDBP), Vision 2020 Umurenge Programme, Performance contracts (*Imihigo*), among others. In the process of sustainable development, Rwanda is also committed to protect its environment. It has thus participated in all of the World Summits on Environmental Protection and Sustainable Development and the resolutions of these summits have been incorporated into the government' policies and laws, both on the national and local levels. Consequently, there is a link between such policies with achieving the MDGs by 2015 [5].

Recognizing its importance in sustainable development, the Netherlands Development Organization (SNV) supports the formulation and implementation of national programmes on domestic biogas in some developing countries [1], including Rwanda. In Rwanda, the first record of the construction of domestic biogas plants dated back to 1982. On the invitation of the FAO, a biogas consultant from Nepal constructed 4 biogas plants ranging in size from 8 to 20 m^3 at the «*Projet de Développement du Petit Elevage*» at Kabuye. At the same time, training course on domestic biogas was organized for technicians. Following this course and with support from SNV/Rwanda, plants were constructed in Rwesero near Lac Muhazi and at the PADEC Project in Murambi [1].

Today, Rwanda finds itself at a crossroad, moving from the humanitarian assistance phase associated with the 1994 genocide into one of sustainable development. Since 1994, the Government of Rwanda has stabilized the political situation, whilst putting the economy back on track with considerable assistance from development partners. However, the challenges remain daunting. Although Rwanda has made significant progress from the devastated nation that emerged from the 1994 genocide, it still remains a severely under-developed, agrarian based economy with around 60% of the population living under the poverty line [6].

National domestic biogas program have a direct positive effect on rural people's energy, environment, health and agricultural production. It shortly means that the domestic biogas promotes all the dimensions of sustainable development. However, more clarifications are needed to know at what extent these investments are profitable at household level. The main objective of this paper is to analyze the effects of domestic biogas on sustainable development in Rwanda, with Muguga Sector of Gakenke District, Rwanda.

2. Material and methods

2.1 Sources of data

Data used for analyzing the effects of domestic biogas on sustainable development were collected from ten household heads, purposively selected. This number represents all the households who had constructed the domestic biogas plants on the date of data collection in the study area. A well structured questionnaire was elaborated bearing to the available literature review. It was then administered and asked the respondents about the characteristics of the households, domestic biogas power plants, social effects of domestic biogas plants, economic effects of domestic biogas plants, as well as the appreciation of the respondents about the contribution of domestic biogas plants to environmental protection.

2.2 Data analysis method

Data were analyzed with Microsoft Excel. Frequency counts and percentages have been considered while analyzing the social and environmental effects of domestic biogas, and Net present value (NPV) method has been used to measure its financial profitability. The NPV of a project is the sum of the discounted net flows of a project. The use of NPV as decision criterion means that the decision maker's objective function is the maximization of such a sum. It is a very concise performance indicator of an investment project: it represents the present amount of the net benefits (that is, benefits less costs) flow generated by the investment expressed in one single value with the same unit of measurement. The aggregation of costs and benefits occurring in different years can be carried out by weighting them. The NPV of an investment project is defined as follows [7]:

$$NPV = \sum_{t=0}^{n} \frac{\pi_t}{(1+i)^t} = \sum_{t=0}^{n} \frac{(R_t - C_t)}{(1+i)^t} \text{ ---Formula (1)}$$

where R_t stands for revenue at time t, C_t stands for the cost at time t, π_t stands for the profit, n stands for the number of periods or years, and i stands for the discount rate. The NPV is a very simple and precise performance indicator. A positive NPV, NPV>0, means that the project generates a net benefit (because the sum of the weighted flows of costs and benefits is positive) and it is generally desirable either in financial terms or in economic terms.

3. Results and discussions

3.1 Distribution of the responds

For the purpose of this study, the respondents have been distributed according to their gender, profession, level of education, family size, volume of the domestic biogas plant, as well as the household's cattle size. The gender distribution of the respondents is summarized in the table below.

Table 1: Gender distribution of the respondents

Sex of respondents	Number of respondent	Percentage
Male	7	70
Female	3	30
Total	**10**	**100**

Source: Field survey, July 2013

According to the above table, the number of male respondents (70%) dominates the number of female respondents. This means that among the household heads who responded our questionnaire, 7 of them (70%) were men and 3 (30%) were women.

Table 2: Distribution of respondents according to the number of persons in household

Number of persons in household	Number of respondent	Percentage
Five persons	2	20
Six persons	5	50
Seven persons	1	10
Ten persons	1	10
Eleven persons	1	10
Total	**10**	**100**

Source: Field survey, July 2013

The table 2 above shows that the family size of people using domestic biogas plant in Mugunga Sector is 8 persons.

Table 3: Distribution of respondents according to the profession

Occupation of respondents	Number of respondent	Percentage
Farmers	7	70
Others	3	30
Total	**10**	**100**

Source: Field survey, July 2013

The table 3 above shows that the 70% of the respondents are farmers, whereas 30% have different jobs than farming.

Table 4: Distribution according to the level of education for respondents

Education level of respondents	Number of respondent	Percentage
Primary education	5	50.0
Secondary education	5	50.0
Total	**10**	**100.0**

Source: Field survey, July 2013

The table 4 above indicates that 50% of the respondents finished primary education and the remaining 50% did secondary education.

Table 5: Distribution of respondents according to the volume of biogas plant

Volume of biogas plant	Number of respondent	Percentage
$4m^3$	4	40
$6m^3$	5	50
$8m^3$	1	10
Total	**10**	**100**

Source: Field survey, July 2013

According to the content of the table 5 above, 40% of the respondents have the domestic biogas plant of $4m^3$, 50% of the respondents have the biogas plants whose size is $6m^3$, and the remaining 10% have the biogas plant of $8m^3$ size.

Table 6: Distribution of the respondents according to the cattle size

Number of cows in household	Number of respondents	Percentage
2	6	60
3	3	30
4	1	10
Total	**10**	**100**

Source: Field survey, July 2013

According to the table 6 above, 60% of respondents own 2 cows, 30% of respondents own 3 cows and 10% have 4 cows. This means that the cattle size is enough to run the domestic biogas plant. It also means that these households produce milk and organic fertilizers with which they earn money by selling milk and bio-slurry, increase crop production and save money by using the self-produced fertilizers. They can therefore achieve sustainable development in their households and promote it in their operations areas.

Table 7. Distribution of the respondents according to the domestic biogas investment cost

Cost of biogas plant (FRW)	Number of respondents	Percentage
750 000	1	10.0
600 000	1	10.0
800 000	3	30.0
400 000	1	10.0
300 000	2	20.0
875 000	1	10.0
450 000	1	10.0
Total	**10**	**100.0**

Source: Field survey, July 2013

According to the content of the table 7, the respondents reported the cost of the biogas investment to be FRW 875 000, FRW 750 000, FRW 600 000, FRW 450 000 and FRW 400 000 respectively confirmed by 10% of the respondents in each case; 20% said that the biogas investment cost was FRW FRW 300 000, and the remaining 30% reported FRW 800 000 as the investment cost of their biogas plants. .

3.2 Home uses of domestic biogas in Mugunga Sector

In Mugunga Sector, domestic biogas is used for home lighting as it has been confirmed by 100% of the respondents. This mean that all the respondents use biogas lamp in their households, they have therefore better home lighting system than traditional lighting methods like kerosene lamps. This system make the children get enough time to revise properly their courses thanks to proper home lighting during evenings.

Besides the use of domestic biogas for home lighting, some respondents (80%) report to use the domestic biogas for cooking everyday whereas some others (20%) say that domestic biogas is used rarely in cooking. The use of domestic biogas in cooking reduces the deforestation by reducing the consumption of fuel wood and charcoal. Yet burning biogas is much cleaner than burning biomass and coal (no indoor air pollution in kitchen) which leads to environmental protection. In addition, the use of biogas for cooking results in providing organic fertilizers known as bio-slurry which replaces chemical and hence used to increase agricultural production and sustain farmers' food security. Apart from being smokeless, biogas does not contribute to global warming.

3.3 Analysis of social effects of domestic biogas in Mugunga Sector

While analyzing the social effects of domestic biogas in Mugunga sector, the researchers have focused on effects to the promotion of gender equality, improvement of health conditions and sanitation, education, and the reduction of the daily workload of women and children. The table below shows the social effects of domestic biogas in Mugunga Sector.

Table 8: Respondents' reports on about social effects of domestic biogas plant in Mugunga Sector

Social effects of domestic biogas	Number of respondents	Percentage
Gender promotion	9	90
Health and sanitation	10	100
Education	9	90
Reduction of daily work load for women and children	9	90

Source: Field survey, July 2013

The table 8 above shows the social effects of domestic biogas, where 90% of respondents reported gender promotion as the main effect of domestic biogas. They confirmed that both men and women are involved in cooking because cooking with biogas stoves is more convenient, easier and faster than with firewood or charcoal stoves; there is also no need of fuel wood collection, so the user can put a pot on the burner and do other activities while the food is cooked. Similarly, all the respondents (100%) said that they have got improved health and sanitation conditions in their households, which means that there is improvement of hygienic conditions, especially of women and children, by eliminating indoor air pollution and by stimulating better management of dung (the stable is cleaned and the dung fed into the digester on a daily basis) and the respiratory illnesses have been reduced. Yet 90% of respondents reported that domestic biogas contribute significantly in promoting education of the children. This means that biogas lamps enable children to revise their courses during evenings.

3.4 Analysis of economic effects of domestic biogas in Mugunga Sector

The analysis of economic effects of domestic biogas in Mugunga sector, the researchers have focused on effects to the provision of addition income sources, promotion of saving, job creation especially during the construction of the biogas plant, provision of fertilizers (bio-slurry), as well as the reduction of home energy expenses. The table below

shows the economic effects of domestic biogas in Mugunga Sector.

Table 9: Respondents' reports on economic effects of domestic biogas plant

Economic effects of domestic biogas	Number of respondents	Percentage
Additional income source	7	70
Saving promotion	7	70
Job creation during construction of biogas plant	3	30
Provision of fertilizers	10	100
Reduction of energy expenses	9	90

Source: Field survey, July 2013

The table above shows the effects of domestic biogas plant in Mugunga Sector whereby 70% of the respondents reported additional income source and saving promotion as the main economic effects of domestic biogas plant. They explained that time saved by cooking on biogas stoves can be used in other economically productive ways. The 30% of respondents also said that there is job creation during construction of biogas plant. It means that National Domestic Biogas Program generates employment opportunities while constructing domestic biogas plants. In the same way, 100% of respondents said that farmers use bio-slurry as fertilizers and added that the use of bio-slurry as a fertilizer improves crop yields compared to traditional manure hence increase in income. Being an organic fertilizer, the bio-slurry improves the soil fertility and hence contributes to soil and water conservation. Yet 90% of respondents also confirmed that the use of domestic biogas reduces home energy expenses, which means that biogas there replaces other sources of energy. This leads the households to save money formerly used for energy expenses and the amount saved should be used in other economic activities.

3.5 Profitability analysis of domestic biogas plant in Mugunga Sector

The profitability analysis of domestic biogas investment in Mugunga Sector was conducted though the NPV method, keeping in mind the funds sources of the construction of domestic biogas plant include 32% for government subsidies, 24% for farmers' minimum contribution, and 44% for bank loan. The lifespan of the domestic biogas plant is estimated to 20 years, and the monthly saving varies from FRW 5 000 to FRW 10 000, that is FRW 7 500 on average. As a part of domestic biogas investment is funded by banks, the bank lending interest rate of 19% (prevailing at the time of data analysis) was considered for this analysis.

With reference to the content of table 7 above, the average biogas investment cost in Mugunga Sector is FRW 417 500. The corresponding government subsidy is FRW 133 600, the minimum farmers' contribution is FRW 100 200, and the potential bank loan is FRW 183 700. This means that farmers' total payments sum to FRW 283 900. The calculations show that the potential annual saving arisen from the use of biogas sums to FRW 90 000.

Putting all the above information together and applying the formula (1) of NVP above described, the calculations of the net present value for domestic biogas investment without government subsidies (given the total investment cost of FRW 417,500) considers the present value of total revenue of FRW 459,078 and the present value of the total cost of FRW 523,099. The net present value without government subsidies is then -64 901. As a result, there is a loss from investing in domestic biogas plant without government subsidies. In contrast, the investment in domestic biogas with government subsidies is profitable as the corresponding net present value is 68,697.

4. Conclusions and Recommendations

This study was conducted to carry out an analysis of domestic biogas as a key driver of sustainable development in Rwanda, Mugunga Sector of Gakenke District has been taken as a case study. A well structured questionnaire was administered to a purposive sample of 10 heads of households operating domestic biogas plants in the study area. The findings revealed that domestic biogas promotes sustainable development. Considering the frequencies and percentages, the results from the analysis indicated that some respondents (80%) reported to use the domestic biogas for cooking everyday whereas some others (20%) say that domestic biogas is used rarely in cooking. Yet 90% of respondents reported gender promotion as the main effect of domestic biogas. Similarly, all the respondents (100%) said that they have got improved health and sanitation conditions in their households, which means that there is improvement of hygienic conditions, especially of women and children, by eliminating indoor air pollution and by stimulating better management of dung (the stable is cleaned and the dung fed into the digester on a daily basis) and the respiratory illnesses have been reduced. Yet 90% of respondents reported that domestic biogas contribute significantly in promoting education of the children. This means that biogas lamps enable children to revise their courses during evenings. These results proved that the domestic biogas has improved living conditions of members of households operating biogas plants in the study area. Economically, the calculations of the net present value for domestic biogas investment without government subsidies (given the total investment cost of FRW 417,500 considers the present value of total revenue of FRW 459,078 and the present value of the total cost of FRW 523,099. The net present value without government subsidies is then -64,901.

As a result, there is a loss from investing in domestic biogas plant without government subsidies. In contrast, the

investment in domestic biogas with government subsidies is profitable as the corresponding net present value is 68,697. Now that the domestic biogas has replaced different sources of home energy, the consequence was that environment as saved as the biomass and charcoal reduced, the bio-slurry improve the soil fertility and contributed to the soil and water conservation. It was then concluded that the domestic biogas helped households improve their social living conditions, increased the economy of these households diversify the sources of income and reduce home expenses, and the use of biogas led to environmental protection in the study are. In other words, domestic biogas promoted socially, economically and ecologically the sustainable development of Mugunga Sector of Gakenke District, Northern Rwanda.

It is recommended to the government to strengthen the domestic biogas program, to encourage research that aims at finding ways how biogas be used with different electrical apparatuses; to the households operating the domestic biogas plants to use it optimally so as to save money, environment and improve their living conditions; and to the local authorities to sensitize farmers with enough cattle to invest in domestic biogas, rise the people's awareness and train them how well to manage the domestic biogas and how to enjoy its benefits.

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Authors' profile

Maniriho Aristide (M.Sc) obtained his B.Sc and M.Sc from the Department of Economics, National University of Rwanda. His areas of specialization are rural and agricultural economics. He currently teaches with INES-Ruhengeri (Ruhengeri Institute of Applied Sciences), Rwanda.

Uwimana Robert obtained his B.A from the Department of Applied Economics, Institut d'Enseignemnt Supérieur de Ruhengeri, Rwanda