International Journal of Development and Sustainability
ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 7 Number 1 (2018): Pages 220-239
ISDS Article ID: IJDS17120202

The impacts of renewable energy on livelihoods: A case study of biogas adoption in Cameroon

Roland Azibo Balgah [1*], Innocent Ndoh Mbue [2], Kester Azibo Ngwa [3]

[1] *College of Technology, The University of Bamenda, P.O. Box 39 Bambili, NWR, Republic of Cameroon*
[2] *Faculty of Industrial Engineering, The University of Douala, Douala, Cameroon*
[3] *Higher Institute of Agriculture and Rural Development, Bamenda University of Science and Technology, Bamenda, Cameroon*

Abstract

Access to energy is crucial for developing sustainable livelihoods. Renewable energy sources dominate international policy discourses based on their dual capacity to enhance livelihoods and improve the environment. This romantic conceptualization sounds appealing. However, supportive empirical evidence combining different approaches are limited. We evaluate the impacts of biogas adoption on the livelihoods of beneficiaries in Cameroon. We use a structured questionnaire to obtain quantitative data from beneficiary households in seven pilot villages in the Western Highlands of Cameroon, before and after biogas adoption. Qualitative data was elicited through focus group discussions, key informant interviews and field observations. The results revealed that adopting biogas significantly increased human, physical and financial capitals (p=0.06; 0.00 and 0.00 respectively), as well as the social capital of beneficiary households, irrespective of gender. Based on the results, we conclude that adopting biogas technologies can potentially endorse the twin objective of livelihoods and environmental improvement. Conclusion on environmental contribution largely leans on the assumption that renewable energy sources are generally environmentally friendly. This was however only weakly captured through an observed expansion of pasture lands by beneficiaries after biogas adoption. We recommend a wider dissemination of biogas technology in developing countries such as Cameroon, where energy supply is currently problematic.

Keywords: Renewable Energy; Adoption, Biogas; Impact; Livelihoods; Cameroon

Cite this article as: Balgah, R.A., Mbue, I.N. and Ngwa, K.A. (2018), "The impacts of renewable energy on livelihoods: A case study of biogas adoption in Cameroon", *International Journal of Development and Sustainability*, Vol. 7 No. 1, pp. 220-239.

* Corresponding author. *E-mail address:* balgahroland@gmail.com

1. Introduction

Energy is indispensable for human survival and development. Energy supply remains an acute problem for developing countries and especially those in sub Saharan Africa (UNDP, 2001; Audu et al., 2017). A major challenge especially for rural households in such countries remains how to regularly access clean, low cost and environmentally friendly energy sources for household use and industrial development (Karthik et al., 2012). In order to survive, many households in developing countries still depend on nonrenewable sources of energy, whose consumption is increasing over time. In Cameroon for instance, wood consumption for energy supply is estimated to increase at a rate of around 3% per annum. The bulk of wood increase is accounted for by firewood (91.2%) and charcoal (1%), the predominant sources of energy in rural areas (Eba'a Atyi et al., 2016). Overall, about 80% of Cameroonians and almost 100% of rural households depends on woody biomass as their main and only source of energy (INS, 2008; MINEE, 2010). This is skyrocketing deforestation.

In Cameroonian communities where forests are rapidly disappearing, using fuelwood as a major energy source has become expensive. Using fuelwood as a key source of energy is time-consuming, labor-intensive and environmentally unsound (Innocent et al., 2016). Replacing fuelwood with alternative (renewable) sources can potentially reduce deforestation in many Cameroonian communities.

Biogas has been contemplated in recent years as a suitable alternative energy source for fuelwood, for many other African countries in general and for rural households in Cameroon in particular (HPI, 2015, SNV, 2015). In fact, attempts to replace environmentally hazardous energy sources with biogas are underway in many African countries (see for instance Halmin (2012) for such interventions in Kenya, and Tangka et al. (2016) for Cameroon). Between 2012 and 2015 for instance, Heifer Project International (HPI) - Cameroon and the Netherlands Development Organization (SNV) jointly promoted the establishment of over 240 household biogas production plants in Cameroon (HPI, 2015; SNV, 2015).

Biogas is a natural product from the anaerobic biodegradation of organic matter such as animal manure and kitchen waste. It generally consists of 50-70% methane (CH_4), 30-40% carbon dioxide (CO_2) and some traces of Hydrogen, Sulfur and Nitrogen (Xiaohua and Jingfei, 2005, Rafiqul and Mohammad, 2014). Its promotion has been fostered by its proven ability as a sustainable substitute for traditional sources of energy such as natural gas and fuelwood. The hygienic slurry obtained during the biogas production process is a high quality fertilizer, whose application in farmers' fields can potentially increase the incomes of beneficiary households mainly through higher yields (Arllette and Franziska, 2012;Rafiqul and Mohammad, 2014; Tah and Ngwa, 2015). This article assesses the impacts of adopting biogas technologies on the livelihoods of beneficiaries in the Western Highlands of Cameroon.

The article will proceed as follows. The next section succinctly reviews the energy literature, focusing on the relevance and potential contribution of renewable energy sources in general and biogas in particular, to different aspects of livelihoods and the environment. A concise discourse on assessing the impacts of projects will end the section. Section 3 will present the materials and methods implored in the paper. The results will be presented and discussed in section 4, while section 5 concludes.

2. Literature Review

2.1. Biogas: Potentials for enhancing environmental improvement and sustainable livelihoods

Adopting biogas technologies can take place at micro (e.g. household) as well as macro levels (Hamlin, 2012, Arllette and Franziska, 2012, Eba'a Atyi et al., 2016). Apart from cooking, biogas can potentially reduce indoor air pollution, produce energy for lighting, heating, and improve sanitation by reducing pathogens, worm eggs and flies (Urmila et al., 2008). Adopting biogas technologies can potentially reduce workload, as the need for firewood collection reduces. Its usage is accompanied by environmental benefits such as fertilizer substitution, less greenhouse gas emission, improved indoor air quality; and economic benefits, as it reduces expenses on fuel and fertilizer (Buysman, 2009). In addition, the byproduct of biogas production known as bio-slurry is a valued organic fertilizer, cherished by farmers due to its long term impact on soil fertility improvement, food production and wild life conservation (Karthik et al., 2012; Rafiqul and Mohammad, 2014; Tah and Ngwa, 2015). These advantages have stimulated a growing interest in the dissemination of biogas as an alternative source of energy, especially in Africa where energy deficiency remains acute (Audu et al, 2017).

The "Biogas syndrome" spreading across Africa and other developing countries has not left Cameroon indifferent. Development organizations and the government of Cameroon increasingly demonstrate great interest in promoting biogas technology, particularly for rural households. This interest does not only rest on the country's favorable energy policy. It is also motivated by the potential, long term benefits on the environment and on the livelihoods of adopters (Tah and Ngwa, 2015; Audu et al., 2017). Economically, adopting biogas can improve crop yields and at the same time reduce cash outflows during crop cultivation. This is due to the replacement of chemical fertilizers with the use of bio-slurry (byproduct from the biogas process) which thus reduces expenditures on chemical fertilizer (Myles, 2004). Asikainen et al. (2004) for instance conclude that the adoption of biogas leads to income savings by adopting households, mostly through reduced expenditures on chemical fertilizers and fuel wood in India. More so, the use of bio-slurry brings about increase in crop yields and a corresponding increase in income from sales of farm products.

Hamlin's (2012) observation that adopting biogas technologies increased beneficiary households' annual income by almost US$ 353 equivalent in Kenya is amazing. Tah and Ngwa (2015) observed an annual increase of 73% (FCFA221,970, or US$ 363 equivalent) in household incomes as a results of adopting the biogas technology in Cameroon. An increase of almost US$ 1 per day in this case can help some households to escape the vicious cycle of poverty. Similar trends have been reported by Hamlin (2012) for Kenyan households, Myles (2004) and Rafiqul and Mohammad (2014) for India and Bangladesh respectively.

The impacts of adopting the biogas technology from an economic perspective are glaring. But that is not the end of the road. When biogas is used for cooking for instance, it greatly reduces the work load required for collecting fuelwood and cooking using the traditional three-stone fire side (Ferrer et al., 2009; Gautam et al., 2009; Karthik et al., 2012). Garfi et al. (2012) in the Peruvian Andes found out that fuelwood consumption among biogas plant owners dropped between 50-60%, coupled with a one hour reduction in cooking time with the use of biogas. Improved health conditions and change in life style are also associated with adopting biogas technology, as was observed after the installation and use of a biogas digester in South Africa (Green and Sibisi, 2002). Katuwal and Bohara (2009), Hamlin (2012) and Garfi et al. (2012) all reported improvements in the health status of household members especially girls and women with the use of biogas. This they contend, resulted from easier and faster cooking, less smoke and pollution (carbon dioxide) involved with the biogas thus reducing the number of head ache cases as well as respiratory problems. Rafiqul and Mohammad (2014) also found similar results in Bangladesh. They observed a decrease in disease prevalence in over 52% of the households who adopted the biogas technology. Further, beneficiaries were reported to feel safer using the biogas technology, at least as compared to industrially produced gas with a high probability of exploding. Some families found milking easier especially in the night due to the lighting system provided to them by their biogas plants.

While human capital is mostly affected through improved health conditions such as reduced eye infections from less smoke and respiratory diseases, it can also be improved by the number of times household eat a day as well as the number of times they eat with fish and/or meat. Amrouk et al. (2013) reported that all four beneficiary countries of the commodity project on Smallholders' Market Access in Developing Countries (Ethiopia, Peru, Tanzania and Zambia) implemented by the Food and Agricultural Organization (FAO) recorded improvements in food security as a result of increased agricultural productivity and excess food from sales during farming, harvesting and off seasons.

There have also been reports of positive impacts of biogas plants on the environment. A shift to biogas from fuel wood results in less dependence on forests, thereby checking their indiscriminate and unsustainable exploitation. MINEE (2010) reports that the use of biogas in place of fuel wood in Cameroon can reduce consumption of fuel wood by about 3tons per year. Myles (2004) and Asikainen et al. (2004) reported that the reduction of fuel wood and dung as cooking fuels and the use of dung as raw material for the biogas plant did not only reduce the pressure on forests, but also increase soil fertility while reducing soil degradation through the use of bio-slurry. Also, there was a corresponding increase in wildlife conservation, reduce green house gas emissions, global warming and climate change. Dhingra et al. (2011) also revealed that households who adopted biogas technologies emitted 48% less greenhouse gases than households without biogas systems.

It would be wonderful, if these multifaceted impacts can accrue to beneficiaries at the same time. In Cameroon in particular, subsidy-based biogas programs have generally been at the forefront of introducing innovative biogas technologies (Tah and Ngwa, 2015). Subsidies are likely to phase out in the near future. One way to guarantee continued interest in promoting biogas technologies into many needy communities is to identify, capitalize and continuously demonstrate the merits of pilot biogas projects. It is based on this premise that this paper examines the impacts of the Heifer Project International (HPI) domestic biogas production project on the livelihoods of the farming household in the Western Highlands of Cameroon.

2.2. Assessing the impacts of development projects

Considerable attention has been given in the past to the potential impacts that development projects have on beneficiary households, communities and institutions throughout the world. Assessing the impacts of development projects is important to assist planners, decision-makers and implementing institutions in understanding what types of changes accompany specific development projects, and what adjustments may be necessary in future interventions. Impact assessments therefore indicate if development projects impacted desired effects on the project beneficiaries and what direction such interventions should take in the future to maximize impacts (Edwards, 2000; Amrouk et al., 2013).

Several approaches can be applied independently or in combination to assess the impacts of development projects. They include among others experimental and quasi-experimental approach, theory-based approaches, the conventional approach, participatory approach and the livelihoods approach (Caroline and Karim, 2000; Crawford et al., 2008; Amrouk et al., 2013).

The experimental and quasi-experimental approaches use statistical and non-statistical techniques to make comparison between control (non-beneficiary) and treatment (beneficiary) groups (Amrouk et al., 2013). In this approach, any significant differences between the two groups are attributed to the project intervention. This approach heavily relies on high motivation of the control group to participate in the analysis. However, there is high risk of change in behaviour and cooperation by the control group over time. More so, the expensive nature of these types of analyses limits their application in project impact assessments. Due to this shortcoming, before and after comparisons of the beneficiary group based on variables attributable to the project intervention are increasingly being used (Khandler et al., 2010).

In the theory-based approach, impact evaluations are based on key inputs, expected outcomes and the underlying assumptions about how these inputs would lead to the desired outcomes (USAID, 2006; White, 2009; Amrouk et al., 2013). In this sense, the link between inputs, outcomes and impacts are analysed to build up an argument as to whether theory has been transformed into practice. It therefore traces how project activities and outputs cause outcomes and how these in turn lead to desired impacts. This key advantage of this methodology is that it tackles attribution problems mostly through selection of appropriate indicators of change (White, 2005 and 2009; Rogers, 2009). White (2005) for instance successfully used the approach in evaluating the impacts of an Integrated Nutrition Project in Bangladesh. His conclusions suggest that the theory-based approach is quite appropriate, especially for evaluating the impacts of interventions issues with strong existing theoretical backgrounds, on the basis of which expectations can be properly formulated prior to project implementation.

The conventional approach focuses on whether the project has met its stated objective and has achieved its overall goal. Essentially, it draws on effectiveness, efficiency, relevance and sustainability to evaluate both the intended and unintended project impacts. Conventional impact evaluations are conducted during the project implementation, at completion and some years after completion (Caroline and Karim, 2000). Because the evaluators work only with indicators that were defined at the start of the project, this approach is criticised for distancing itself from the expectations of the project participants/beneficiaries. In other words, the level of participation of beneficiaries especially in defining the measurement indicators is extremely low. Critics of this approach point to the advantages of more participatory approaches in completing the picture.

Participatory approaches require a stronger involvement of project beneficiaries, who should be best involved at all stages of the evaluation process. Interviews and focus group discussions are conducted with the project beneficiaries to obtain qualitative and quantitative data on the project impact, using indicators previously validated by the beneficiaries (Crawford et al., 2008). Depending on the evaluation body/team, other stakeholders such as project implementers and policy makers are also interviewed for triangulation and collection of base line information on the project especially with respect to predefined project objectives and goals (Caroline and Karim, 2000; Crawford et al., 2008). With this approach, two methods can be adopted. The first method involves the collection of information from the project beneficiaries and from a control group made of households in the same or neighbouring communities for comparative analyses (similar to the experimental approach described above). The second method involves collecting and comparing information solely from the project beneficiaries *before* and after the project implementation (quasi-experimental approach). In both methods, comparative analyses are conducted for any significant differences (see for instance the work of Crawford et al. (2008) in the Padre Ramos Estuary Nature Reserve of Nicaragua, and Balgah et al. (2012) in their comprehensive impact assessment of the 2012 Babessi floods on people's livelihoods in rural Cameroon).

Sometimes, the above mentioned approaches are used in combination, to increase validity of results. Amrouk et al. (2013) for instance used a theory based approach together with the participatory approach in their work in Ethiopia, Peru, Tanzania and Zambia. The livelihoods approach however is a specific combination of the conventional and the participatory approaches. Very often it will employ a variety of conventional data sources, is people-centred and tries to assess impacts based on people's own perspectives. The UK Department for International Development (DFID), Oxfam, the Overseas Development Institution (ODI) the African Wildlife Foundation and the Swiss Agency for Development and Cooperation (SDC) for instance have all successfully applied this approach in the past, to evaluate development projects implemented by their organizations (DFID, 1999; Ludi and Slater, 2008).

Given the advantages, a combination of approaches was applied in this study. A questionnaire was designed to quantitatively capture the before and after livelihood situations of beneficiaries. Baseline data collected at the start of the project was also used to assess to what extent changes in livelihoods could be attributed to the project. This was combined with more qualitative approaches. This significantly reduced the need and costs for involving a control group. Further specifications will be provided in the materials and methods section.

3. Materials and methods

3.1. Background of the study area

Cameroon is an agriculture-dependent country in Central Africa, with over 20 million inhabitants distributed in 10 administrative regions (HP1, 2015). The Western Highlands in Cameroon extends through the Western and the North West administrative regions. It borders the *South Cameroon Plateau* to the southeast, the *Adamawa Plateau* to the northeast, and the Cameroon coastal plain to the south. It is a famous agro-ecological zones in Cameroon, and lies between latitude $5^{0}40^{1}$and7^{0} North and of the Equator and longitude

$9^0 45^0$and11^0East of the prime meridians (Innocent et al., 2016). It is characterised by a short dry season of about four months (November-February) and a wet season of about 8months (March-October) with the months of August and February as the coldest and hottest (10^oC and 30^oC respectively). The mean annual temperature ranges between 15ºC-28ºC. Rainfall is generally high ranging from 1300mm to about 3000mm per year (Moloa and Lambi, 2006). In terms of vegetation, it is made up of mixed forest and savannah grassland. The Western Highlands hosts the largest number of flora and fauna on in the country. Most scholars have pointed to rapid deforestation; land degradation and loss of endemic species as key issues for concern in this agro-ecological zone, especially in the last two decades (Abbot et al., 2001, Moloa and Lambi, 2006, Epule et al., 2014, Innocent et al., 2016). These scholars seem to converge on the fact that the interaction between, or rather interference of man with nature is mainly responsible for degradation, which is largely visible across the agro-ecological zone.

Many households in the region rely heavily on firewood for energy, bush meat for animal protein, and on fertile forest areas for food production. While efforts to restore specific ecosystems have been undertaken and are widely reported (for instance Maisels et al., 2001, Fonjong 2008, Asaah et al., 2011), introducing alternative energy sources especially for rural households in the Western Highlands of Cameroon who depend almost entirely on fuelwood for cooking has been largely neglected. In fact self-consumption of collected fuelwood in rural areas in the western highlands of Cameroon is estimated at 71,027 tons per annum (HP1, 2015; Eba'a Atyi et al. 2016). In the future, this will be exacerbated by rising population and an emerging land market even in the rural areas. With this in mind, Heifer Project International (HPI), an International NGO embarked on a project to introduce and promote the use of biogas among households in the Western Highlands of Cameroon. This paper assesses the impacts of the project on the livelihoods of the pilot project beneficiaries.

3.2. Introducing heifer project international and its biogas project

The defunct Heifer Project International (HPI) Cameroon was an International NGO with its national Head Office in Bamenda, Cameroon. HPI Cameroon's mission (which is similar to the overarching mission of the International Organization) was to work with communities to end hunger and poverty and to care for the earth. HPI operated in six of the ten regions of Cameroon, implementing grassroots integrated smallholder animal agriculture projects for over 40years before leaving the country in 2016 (Brooke, 2015).

One of its programs in the Western Highlands, the zero-grazing smallholder dairy production was the brainchild for the biogas development program, as the latter strongly depends on the former for the supply of cow dung, needed to sustain the biogas digesters. In addition, it was believed that biogas production will reduce pressure on the forest resources, improve the yields on the largely subsistence agricultural fields and enhance long term economic and social welfare of farming households. With these targets in the forefront, HPI Cameroon embarked on a pilot project on domestic biogas in the Western Highlands of Cameroon, from January 2012 to December 2013. Project funding came mainly from HPI and the Global Environment Facility (HPI, 2011). The project was designed with the objective to contribute to restoring land productive capacities and reducing greenhouse gas emissions from the dairy farms, while improving the livelihoods of beneficiary households through the adoption of domestic biogas technology. The project covered seven villages (Kedjom Ketingoh, Vekovi, Akum, Bamendakwe, Awing, Njong-Santa and Mbei-Santa) in Mezam and Bui divisions of the Northwest Region of Cameroon (which is part of the Western Highlands).

The biogas project targeted 800 beneficiaries in 100 resource-limited households who were to integrate domestic biogas technology into established dairy cattle farms. Only farm households that had an average of 3 dairy cattle under zero-grazing system were to be involved in the pilot phase (HPI, 2011). The project will contribute to reducing land degradation and enhance the government of Cameroon's National Energy Plan for Reducing Poverty (PANERP) through increased access to (renewable) energy in rural areas (IMF Country report for Cameroon, 2010). Today, one would say that it would also contribute to achieving Goals 1, 2, 7 and 8 of the Sustainable Development Goals (United Nations, 2015).

3.3. Impact assessment design

The overarching approach adopted for the project evaluation was the participatory approach. Since a control group was not included at the start of the project, only the project beneficiaries were considered in the impact assessment. The evaluation combines both quantitative and qualitative methods. Quantitative data on the one hand was collected on aspects such as change in fuelwood and fertilizer use, shifts in expenditures on fuelwood and chemical fertilizers, household income, income from sales, food consumption dynamics, age, household size, dairy, farm sizes, etc. These variables were framed in a structured questionnaire. The same questionnaire with similar variables was used before and after biogas technology was adopted (see for instance Khandler et al. 2010 for further discussions on this approach). On the other hand, qualitative data was collected on issues regarding general health status of household members, level of satisfaction with biogas plants and general management of biogas plants. The evaluation carried out in May 2015 lasted for 27days. It was undertaken by a multidisciplinary, gender-sensitive team of 6 experts made up of a rural engineer, an economist, a livestock specialist, a rural development expert, natural resource manager and a statistician.

3.4. Sampling techniques

Sampling was done using a stratified random sampling technique. Stratification was initially done to include both male and female beneficiaries in the final sample. Besed on Teddie and Tashakkori (2003) as well as Teddie and Yu (2007), the sample size (sample assisted households) of each village was calculated proportionately to the beneficiary population size (total assisted household) of the village in order to yield better precision in the analyses. The sample household sizes were determined by the following equation:

$$n_h = (N_h / N) * n \quad 1$$

Where n_h is the sample household size for village h, N_h is the population size for village h, N is total population size, and n is total sample size.

The selection was then purposively adjusted to achieve at least a 40% female participation. This adjustment was necessary, as diary animals are mostly kept by male farmers, considering that the patriarchal system of inheritance dominant in the area limits women's landed property rights (Balgah, 2016). The final sample included 45 beneficiaries (27 male and 18 female) distributed in seven villages in the Western Highlands as follows: Kedjum Ketinguh (4); Akum (4); Bamendankwe (9); Santa Mbei (6); Santa Njong (9); Awing (6) and Vekovi (7) (see Figure 1).

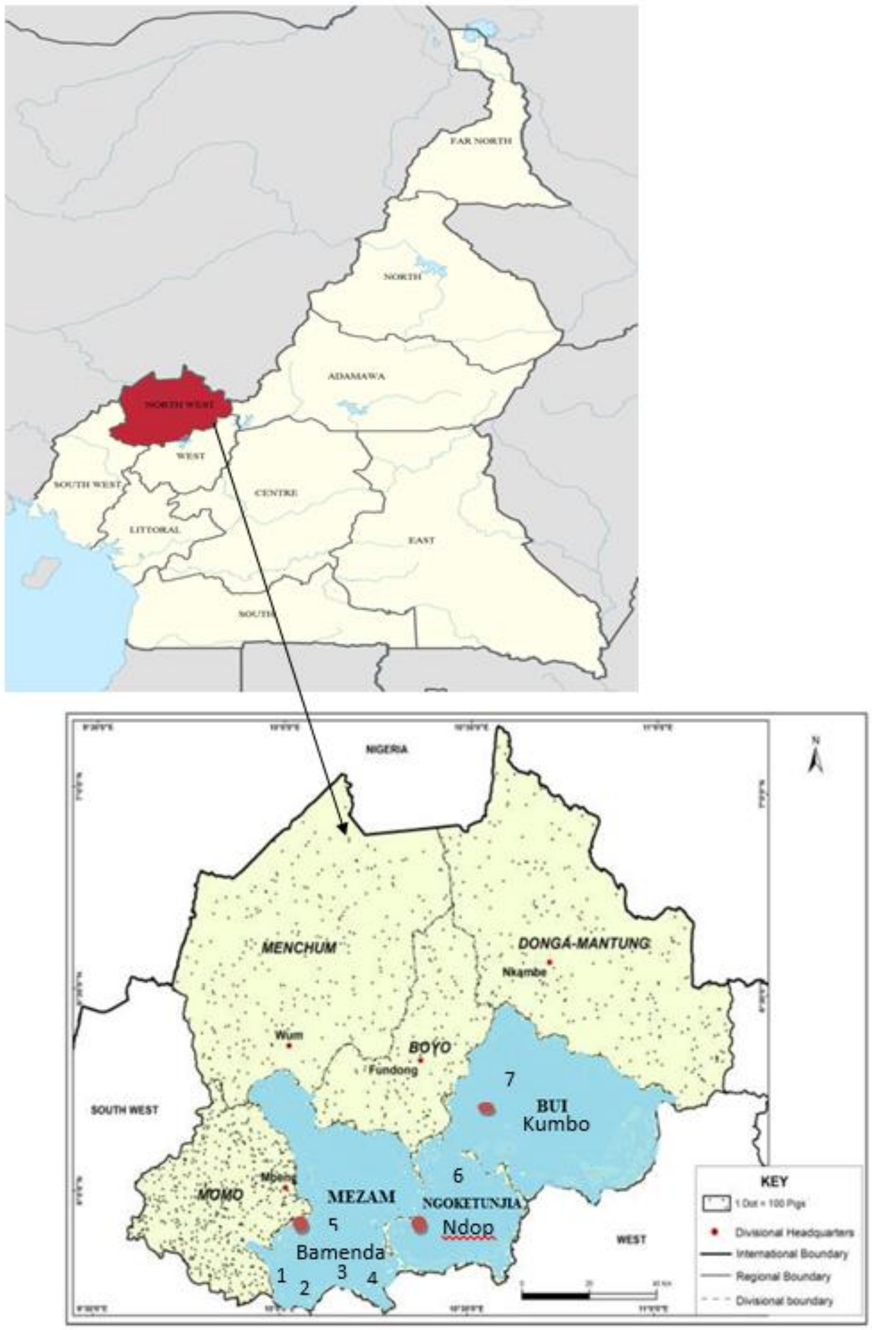

Figure 1. Map of study area in the North West Region of Cameroon (Source: Adapted from Ngala and Kimengsi, 2017)

Notes:

1. The large red dots indicate the divisional capitals of respective divisions in which the research villages are located.
2. The numbers (1-7) represent the sample villages: 1=Awing; 2=Akum; 3=Santa Mbei; 4=Santa Njong; 5=Bamendankwe; 6=Kedjum Ketinguh; and 7=Vekovi

3.5. Data collection and analysis

Quantitative data was collected by the team members using structured, pre-tested questionnaires in all seven project sites. Focus group discussions, key informants interviews, and observations which complemented the questionnaire were carried out together by the research team members, of different disciplines. This allowed for a holistic impact assessment of the biogas project. Quantitative data was analysed using Excel and SPSS (Statistical Package for Social Sciences) version 20.0. A before-and-after comparative analysis was done using selected livelihood variables to check for significant differences attributable to biogas adoption. This was done using the different forms of capitals (social, human, physical and financial) as defined in the Sustainable Livelihoods Framework (Scoones, 1998, Ludi and Slater, 2008). Qualitative data collected using focus group discussions, key informant interviews and observations were used to triangulate the results obtained from the questionnaires, and to enrich the data interpretation process. The results are presented and discussed in the next section.

4. Results and discussions

4.1. Socio-economic description of sample

Figure 2 presents the distribution of the sample by gender. 60% of our sample was male while 40% was female. Only a small proportion of the beneficiaries as shown in Table 1 had completed high school or had above high school level of education (6.7%). The majority of them have only completed primary school education (46.6%). The remaining 40% did not even completed primary school level of education. One can say here that HPI Cameroon initially did a good job in targeting poor households in the research region, based on the deficiency in human capital observed in the sampled households.

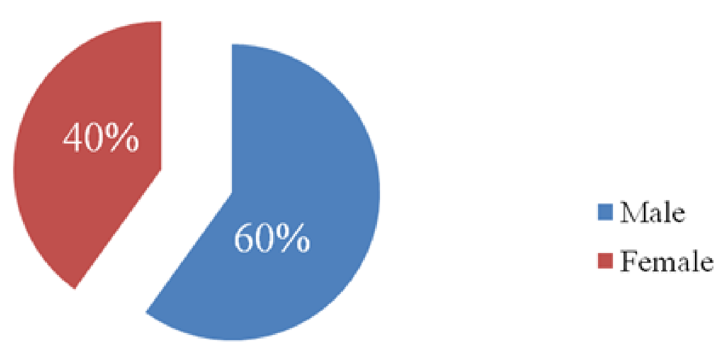

Figure 2. Gender distribution of sample population (Source: Field data analysis)

Table 1. Highest educational level of respondents

Educational level	Maximum
Did not complete primary school	40%
Completed primary school	46.6%
Completed secondary school	6.7%
High school and above	6.7%

Source: Field data analysis

Table 2. Mean age and household size

	N	Minimum	Maximum	Mean	Std. Deviation
Age of farmer	45	25	70	48.8	10.9
Household size	45	2	15	7.5	2.3

Source: Field data analysis

It is further observed from Table 2 that the mean age of the respondents was about 49 years while the average houssehold size was 8 persons. However, while some of the benficiaries were as young as 25 years, others were as old as 70 years at he time of interview. Also, the household size is skewed, as it ranged from 2 to 15 persons at the time of interview, some had as many as 15 persons. A conjecture here is that the household size did not likely influence biogas adoption.

4.2. Impact of adopting Biogas technology on livelihoods

This section will presents and discusses the impacts of the biogas project based on the different forms of capitals outlined in the Sustainable Livelihoods Framework that were included in the data collection. These include human, physical, financial and social capitals (Scoones, 1998, DFID, 1999, Ludi and Slater, 2008).

4.2.1. Human capital

Human capital was captured in this study using the health status of household, the number of meals eaten by the households per day and the frequency at which fish and/or meat was consumed at the household. Differences before and after the project intervention will indicate the extent to which adopting biogas energy production systems impacted the beneficiaries. Looking at food consumption and nutrition dynamics, Figure 3 reveals that, on average, the number of meals per day (3 times) did not change since the adoption of the biogas technology. However, the number of times luxury food (meat and or fish) was eaten a week on average increased from 3 to 4 times per week (P = 0.06). This situation is similar for both the male and female beneficiary households (Table 3). Though the results are only significant at the 10% level, they represent increased consumption at beneficiary household level, probably as a result of reduction of the purchase of fuel wood with the adoption of biogas. Focus group discussions suggest that households consume more varieties of food types as the cultivated varieties could be increased as a consequence of bio-slurry application after biogas technology was adopted. This was the view point of almost 90% of the beneficiaries. Increase in the number of crops cultivated culminated into increased food sales, especially for vegetable crops.

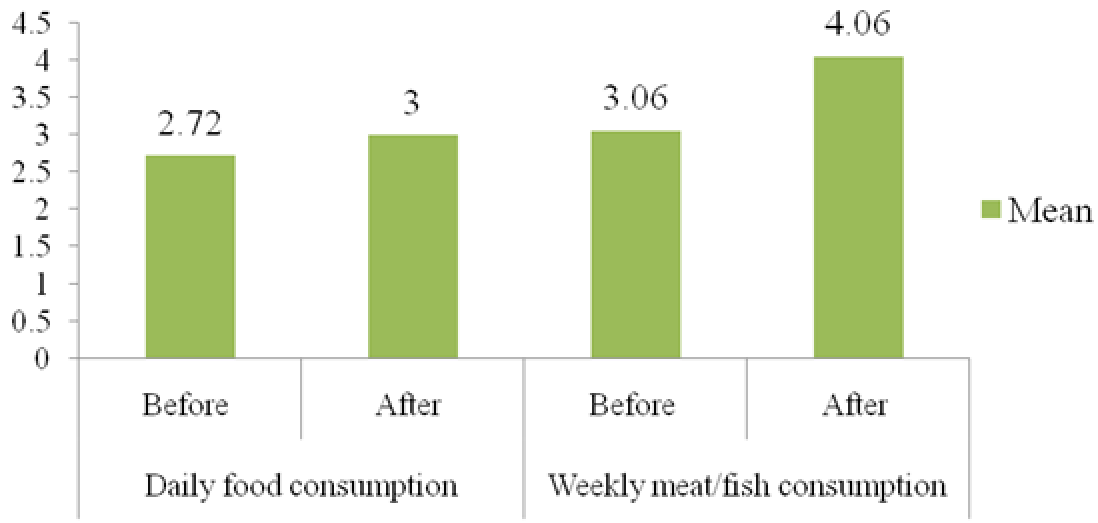

Figure 3. Food consumption dynamics (Source: Field data analysis)

Note: [a] The p value for daily food consumption before and after biogas adoption was 0.09, while that for weekly consumption of meat and/or fish was 0.06

Table 3. Food consumption dynamics by gender

	Gender	Mean	Std. Deviation	Std. Error Mean	Sig.
Number of times household ate with meat/fish a week before biogas	Men	2.86	2.23	0.48	P>0.05
	Women	3.36	2.13	0.57	
Number of times household ate with meat/fish a week now	Men	3.82	2.24	0.48	P>0.05
	Women	4.43	2.17	0.58	
Number of times household ate before biogas construction	Men	2.64	0.49	0.11	P>0.05
	Women	2.86	0.36	0.10	
Number of times household eat now	Men	2.91	0.43	0.09	P>0.05
	Women	3.14	0.86	0.23	

Source: Field data analysis

Additional household income motivated an increase in the purchase of luxury foods such as fish and/or meat. Consumption of nutritious/more balanced meals, reduced cooking work load and more time for leisure were some of the additional fallouts for adopting the biogas technology. Reduced smoke from biogas stoves was conjectured to have contributed to reducing eye problems and respiratory diseases for beneficiaries. This information leads us to conclude that the biogas technology had an overarching positive impact on the health conditions of beneficiary households. This was view point of about 75% of all beneficiaries. The results were not different for female and male beneficiary households (74.1% for female and 72.2% respectively). These results confirm the findings of Rafiqul and Mohammad (2014) in Bangladesh where 80% of biogas plant owners reported better health conditions after adopting and using the biogas technology.

4.2.2. Physical capital

Physical capital was assessed based on the number of dairy cattle, the farm size on which slurry was used for crop production as well as for pasture improvement activities.

The mean heads of dairy cattle owned by beneficiaries increased significantly after households adopted the biogas technology, from one to three (P = 0.00). Due to the benefits of using biogas, farmers were motivated to increase their dairy stock so as to have constant and adequate supply of manure to feed in to the bio-digester. Nevertheless, information from focus group discussions revealed that some farmers go in for dairy production to replace old ones and have even sold some to other farmers whose livestock had died.

Table 4. Analysis of Biogas Adoption on Physical capital

		Minimum	Maximum	Mean	Std. Deviation	P-value
Number of dairy cattle owned by Household	Before	1	1	1	0.000	0.00
	After	1	5	3.14	4.74	
Land for agricultural production (Ha)	Before	.5	6.0	1.60	1.55	0.05
	After	.5	4.0	1.22	1.04	
Land for pasture development (Ha)	Before	.32	1.5	0.65	0.47	0.52
	After	.41	2.5	0.71	0.57	

Source: Field data analysis

Results from table 4 indicate that on the one hand, the average land area cultivated for agricultural production per households reduced after the adoption of the biogas technology, from 1.6ha to 1.2ha). On the other hand, pasture slightly increased from 0.65ha to over 0.7ha. This is logical, as more cattle warrants increase in pasture establishment. The expansion of pastures is only minimal probably due to land scarcity. Furthermore, information from focus group discussions and key informant interviews revealed that farming around the homesteads has intensified due to increased manure availability. Cultivation of distant farms has significantly reduced, due to higher yields from on nearby home gardens, as a result of the application of slurry emanating from the biogas production process.

It was observed that on average, women own one dairy cattle less than the men (Table 5). This is explained by patriarchy, which limits women's access and control over (pasture) in the research region (Balgah, 2016). This is also a probable explanation as to why the area under cultivation with bio-slurry is significantly lower for female than male beneficiaries (0.5ha and 0.9ha respectively, P = 0.01).

Table 5. Number of Dairy animals and farm size owned by farmer

	Gender	Mean	Std. Deviation	Std. Error Mean	F-test (P-value)
Number of dairy cattle owned by farmer	Men	4.0	5.99	1.15	3.11
	Women	2.0	0.81	0.20	(0.09)
Farm size on which biogas Slurry is applied (Ha)	Men	0.90	1.07	0.22	8.87
	Women	0.53	0.40	0.11	(0.01)

Note: [a] The mean number of dairy cattle has been rounded up to the nearest whole number

4.2.3. Financial capital

Perhaps the highest impact of the biogas project is reflected in growth of household incomes and expenditures, as presented in Table 6. Analysis of collected data demonstrates that farmers witnessed a significant upsurge in the financial asset front after adopting biogas technologies, mainly as a result of reduced expenditures on fuelwood and chemical fertilizers, and increased sales of agricultural products with the advent of biogas. The results support previous findings in the research region (see for instance Tah and Ngwa, 2015). On average, farmers spent FCFA71,020 (US$118.37) less on fuelwood and FCFA20,610 (US$ 34.35)less on chemical fertilizers per annum after project adoption, since biogas replaced fuelwood previously used for cooking, and bio-slurry reduced the need for inorganic fertilizers. Bio-slurry application caused a spring in crop yields on adopters' fields. Financially, a mean increase of FCFA54,680 (US$91.13) from sales of excess crops from the subsistence farms was reported. This is mainly due to bio-slurry application. In reality, the income from crop sales can be higher, since the current calculations were done by considering on the yields of maize and beans, the two most cultivated crops in the region.

A summation of net savings on fuel wood and chemical fertilizer per annum, as well as the net income from additional crops sold amounts to FCFA146,310 (US$243.85) per household per annum. This represents an overall increase in household income of about 73%, compared to the annual mean income of FCFA200,800 (US$334.67) per household per annum before biogas adoption. This increase led to rising annual savings of FCFA75,600 (US$126). Clearly, adopting biogas has been accompanied by direct and indirect benefits for adopters. Prospects of improving the financial status of the poor through biogas adoption technology exist, at least as demonstrated by our case study from Cameroon. The above results support previous findings. Hamlin (2012) for instance reported that adopters of biogas technology in Kenya witnessed an increase in yearly financial savings of about 3000Kenyan Shillings (352.8US$ equivalent).

Table 6. Financial impacts of home biogas plants

Variable		Minimum	Maximum	Mean	Std. Deviation	P-value
Quantity of fire wood used yearly (in local trucks)	Before	30.4	152	65	27	0.01
	After	6.08	91	30	18	
Annual expenditures on fire wood/FCFA	Before	0	306,000	142,040	115,540	0.00
	After	0	306,000	71,020	73,670	
Annual expenditures on chemical fertilizers/FCFA	Before	0	180,000	50,500	32,380	0.00
	After	0	162,000	29,890	30,100	
Income from sales/FCFA	Before	0	203,000	32,520	50,600	0.03
	After	0	660,000	87,200	135,050	

Notes: [a] Currency amounts have been rounded to the nearest FCFA

[b] Number of local trucks has been rounded to the nearest whole number

[c] 1 US $ = FCFA 600

4.2.4. Social capital

Analyses of outcomes from focus group discussions suggest that beneficiaries increased their social networks as a result of the biogas project. Networks were important for the acquisition of new information and experience-sharing on biogas and beyond. Consultation and technical/maintenance fees demanded by experienced members to other (needy) adopters were grossly lower than market rates. Over 50% of all needy farmers reported to have benefitted at least once from completely free services from experts in their networks. Even gender roles changed with biogas adoption. Male children were reported to have developed interest in cooking in all the households, with the availability of biogas. Cooking is a socio-cultural activity almost exclusively reserved for the female children in many households in North West Cameroon (Balgah, 2016). In general, cooking time was greatly reduced, especially for the girls and women in the adopting households. Thus social relations at household level among men, women and children (both boys and girls) have improved due to the adoption of the biogas technology, as it has rendered cooking a forum for family reunion.

5. Conclusion and Recommendations

The emphasis on the role that energy in general and renewable forms in particular can play in developing and sustaining livelihoods around the globe is quite strong. Empirical evidence is largely insufficient to support this widely accepted contention in the energy-livelihoods-environment discourse. The objective of this paper has been to contribute to the discourse, by empirically evaluating the impacts of home constructed biogas plants on the livelihoods of farming households. Data was collected from 45 pilot beneficiaries of the

2012-2013 pilot biogas project implemented by Heifer International in some communities in the Northwest Region of Cameroon. The household socio-economic (livelihood) benefits of biogas were analyzed using human, physical, financial and social capitals as defined in the Sustainable Livelihoods Framework (Scoones, 1998, DFID, 1999). Our results reveal and conclude that biogas adoption improved the living conditions (livelihoods) of beneficiary households from the human, physical, financial and social capital fronts, with no significant difference between male and female headed households. Some aspects that contribute to the environment (e.g. increasing pasture lands) were also observed. Given the nature of the research, direct environmental impacts could not be measured (for instance in terms of increased carbon sequestration). In general, our empirical example demonstrates both direct and indirect livelihood benefits for biogas technology adopters. We therefore conclude that adopting biogas in particular and renewable energies in general hold great prospects for enhancing sustainable livelihoods development, particularly in energy-poor, rural areas of many developing countries. The potentials are higher in communities where livestock activities are intense enough to sustain biogas production systems. Governments and development organisations in partnership with the private sector could further explore possibilities of scaling up innovative biogas projects as one key strategy to achieve the dual objective of developing sustainable livelihoods, while improving the environment. We acknowledge the shortcoming of our work particularly on its inability to adequately assess the environmental impacts of biogas adoption in our Cameroonian case study. However, we implicitly assume this impact, in line with the general advantages of renewable energy sources. This area deserves closer emphasis in future research endeavors.

Acknowledgement

We would like to acknowledge the role of Research Grants from the Volkswagen Foundation Germany, and the Ministry of Higher Education-Cameroon in facilitating this work. We are extremely grateful to the anonymous referees for the scientific and thoughtful contributions to the paper.

References

(UNDP) United Nations Development Programme (2001), *Making New Technologies Work for Human Development, Human Development Report,* Oxford University Press, New York.

Abbot, J.I., Thomas, D.H., Gardner, A.A., Neba, S.E., and Khen, M.W. (2001), “Understanding the links between conservation and development in the Bamenda Highlands, Cameroon”, *World Development*, Vol. 29 No. 7, pp. 1115-1136.

Agricultural Competitiveness and Sustainability of Rural Areas, Prague, Czech Republic, September 18-19, 2012.

Amrouk, M., Nigel, P., Nicholas, M. and Everjoyce, M. (2013), *The Impact of Commodity Development Projects on Smallholders’ Market Access in Developing Countries*, FAO Commodity and Trade Policy Research Working Paper No. 35, Rome.

Arlette, O. and Franziska, S. (2012), "Effects of biogas production on inter- and in-farm competition", Paper prepared for presentation at the 131st EAAE Seminar on Innovation for

Asaah, E.K., Tchoundjeu, Z., Leakey, R.R., Takousting, B., Njong, J., and Edang, I. (2011), "Trees, agroforestry and multifunctional agriculture in Cameroon", *International Journal of Agricultural Sustainability,* Vol.9 No.1, pp. 110-119.

Asikainen, V., Rintal, J. and Lampinen, A. (2004), *Environmental Impact of Household Biogas Plants in India: Local and Global Perspective,* Master's Thesis, Faculty of Natural and Environmental Sciences, University of Jyvaskyla, India.

Audu, E., Paul, S.O. and Ameh, A. (2017), "Privitisation of power sector and poverty of power supply in Nigeria: A policy analysis*", International Journal of Development and Sustainability* Vol. 6 No. 10, pp. 1218-1231.

Balgah, R., Buchenreider, G. and Mbue, I. (2012), "When Nature Frowns: A comprehensive impact Assessment of the 2012 Babessi floods on people's livelihoods in rural Cameroon", *Jamba Journal of Disaster Risk Studies* Vol.7 No.1, Art. #197, 8 pages

Balgah, R.A. (2016), "Using Access and Control Profiling to Unlock Gender Group Differences in Some Communities in Rural Cameroon", *Asian Journal of Agricultural Extension, Economics and Sociology*, Vol.12 No.3, pp. 1-11.

Brooke, E. (2015), *Changing Directions in Cameroon, World Ark Magazine, Heifer Project International,* https://www.heifer.org/join-the-conversation/blog/index.html (Accessed on 10 October, 2016).

Buysman, E. (2009), "Anaerobic Digestion of Waste", In: Karagiannidis A. (ed) *Waste to Energy. Green Energy and Technology. Springer, London*. pp. 107-135.

Caroline, A. and Karim, H. (2000), *Developing Methodologies for Livelihood Impact Assessment: Experience of the African Wildlife Foundation in East Africa*, ODI Working Paper No. 129, Overseas Development Institute, London, UK.

Crawford, B., Herrera, M., Almanza M. and. Balladares E. (2008), *Impact Assessment of the SUCCESS Program Livelihood Activities in the Padre Ramos Estuary Nature Reserve of Nicaragua.* Coastal Resources Center, University of Rhode Island and Centro de Investigación de Ecosistemas Acuaticos, Universidad Centroamericana.

DFID (1999), Sustainable Livelihoods Guidance sheets, http:www.nssd.net/pdf/sectiono.pdf (Accessed on 20 November, 2016).

Dhingra, R., Christensen, E., Liu, Y., Zhong, B., Wu, C., Yost, M., Remais, J. (2011), "Greenhouse gas emission reductions from domestic anaerobic digesters linked with sustainable sanitation in rural China", *Environment, Science and Technology* Vol. 45, pp. 2345–2352.

Eba'a Atyi, R., Ngouhouo, P., Mvondo, A., Ngoungoure, M. and Sufo, K. (2016), "Economic and Social Importance of Fuel wood in Cameroon", *International Forestry Review*, Vol.18 No.2, pp.1-14.

Edwards, M. (2000), *Community Guide to Development Impact Analysis*, Wisconsin Land Use Research Program, Program on Agricultural Technology Studies, University of Wisconsin–Madison, USA.

Epule, E.T., Peng, C., Lepage, L. and Chen, Z. (2014), "Policy options towards deforestation reduction in Cameroon: An analysis based on a systematic approach", *Land use policy*, Vol.36, pp. 405-415.

Ferrer, I., Gamiz, M., Almeida, M. and Ruiz, A. (2009), "Pilot project of biogas production from pig manure and urine mixture at ambient temperature in Ventanilla (Lima, Peru)", *Waste Management Oxford* Vol. 2009 No.29, pp. 168–173.

Fonjong, L.N. (2008), "Gender roles and practices in natural resource management in the North West Province of Cameroon", *Local Environment*, Vol.13 No.5, pp. 461-475.

Garfí, M., Ferrer-Martí, L., Velo, E. and Ferrer, I. (2012), "Evaluating benefits of low-cost household digesters for rural Indian communities", *Renewable Sustainable Energy Review,* Vol. 2012 No.16, pp. 575–581.

Gautam, R., Baral, S. and Herat, S. (2009), "Biogas as a sustainable energy source in Nepal: Present status and future challenges", *Renewable Sustainable Energy Review*, Vol.2009 No.13, pp. 248–252.

Green, J. and Sibisi, M. (2002) *Domestic Biogas Digesters: A Comparative Study*. In Proceedings of Domestic Use of Energy Conference, Cape Town, South Africa, 2–3 April 2002, pp. 33–38.

Hamlin, A. (2012), "Assessment of Social and Economic Impacts of Biogas Digester in Rural Kenya", *Independent Study Project (ISP) Collection, Paper 1247.*

HPI (Heifer Project International Cameroon) (2011), *Pilot Project on Domestic biogas in the Western Highlands of Cameroon*, GEF small grants project, 2011, Cameroon.

HPI (Heifer Project International Cameroon) (2015), *Evaluation Report on the Pilot Project on Domestic Biogas in the Western Highlands of Cameroon*, HPI, Cameroon.

Innocent, M., Bitondo, D. and Balgah, R. (2016), "Climate Variability and Change in the Bamenda Highlands of North Western Cameroon: Perceptions, Impacts and Coping Mechanisms", *British Journal of Applied Science and Technology,* Vol.12 No.5, pp.1-18.

INS (2008), *Tendances, profil et déterminants de la pauvreté au Cameroun entre 2001 et 2007*. Rapport de l'Enquête ECAM III, Yaoundé. 51 p.

International Monetary Fund (IMF) (2010), *Cameroon: Poverty Reduction Strategy Paper. Reference Framework for Government Action over the Period 2010-2020.* International Monetary Fund, Washington D.C.

Karthik, R., Solmaz, A. and Mohammad, J. (2012), "Household Biogas Digesters-A Review", *Energies* Vol.2012 No. 5, pp. 2911-2942.

Katuwal, H., and Bohara, A. (2009), "Biogas: A promising renewable technology and its impact on rural households in Nepal", *Renewable and Sustainable Energy Reviews,* Vol.13 No.9, pp. 2668-2674.

Khandler, R.S., Koolwal, G.B. and Samad, H.A. (2010), *Handbook on impact evaluation:Quantitative methods and practices*. Washington, DC: The World Bank.

Ludi, E. And Slater, R. (2008), *Using the Sustainable Livelihoods Framework to understand and Tackle Poverty*, Bern: Swiss Agency for Development and Cooperation.

Maisels, F., Keming, E., Kemei, M. and Toh, C. (2001), "The extirpation of large mammals and implications for montane forest conservation: the case of the Kilum-Ijim Forest, North-west Province, Cameroon", *Oryx,* Vol.35 No.4, pp. 322-331.

MINEE (Ministry of Energy and Water Resources) (2010), *Blue Flame for Brighter Future for Cameroon,* National Biogas Program, 2010 Report, 67 p.

Molua, E.L., and Lambi, C.M. (2006), *Climate, hydrology and water resources in Cameroon.* The Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria South Africa.

Myles, R. (2004), "Environmental, Social and other Positive Impacts of Building Household Biogas Plants in Rural India", Paper presented at the World-Council-for-Renewable Energy, May 29-31, 2004, Bonn, Germany.

Ngala, H. and Kimengsi, J. (2017), Mapping epilespsy risks through porcing farming in North West Cameroon, ISABB Journal of Health and Environmental Sciences, Vol. 4 No. 1, pp.1-10

Rafiqul, I. and Mohammad, S. (2014), "Biogas Plant Owner's Opinion about the Impact of Biogas on Health and Environment in Bangladesh", *International Journal of Research in Science, Engineering and Technology*, Vol. 3 No.9, pp. 16111-16119.

Renewable and Sustainable Energy Reviews, Vol.13 No.9, pp. 229–236.
Rogers, P. (2009) "Matching impact evaluation design to the nature of the intervention and the purpose of the evaluation", *Journal of Development Effectiveness*, Vol. 1 No.3, pp. 217-226.

Scoones, I. 1999. *Sustainable rural livelihoods: a framework for analysis*. IDS Working Paper No. 72.

SNV (Netherlands Development Cooperation) (2015) Cameroon: 164 biodigestors for biogas production in Adamaoua *http://www.agenceecofin.com/electricity/0707-30414-cameroon-164-biodigestors-for-biogas-production-in-adamaoua (accessed on 13 September, 2016).*

Tah, C. and Ngwa, K. (2015), "Biogas Production: Impact on Farmers' Incomes", *International Journal of Emerging Trends in Multidisciplinary*, Vol.1 No.10, pp. 199-210.

Tangka, J., Ketuma, C., Ajaga, N. and Viyor, C. (2016), "Modelling the Operation of a Small Generator Set Powered by Scrubbed Biogas from Cow Dung", *British Journal of Applied Science and Technology*, Vol.14 No.1, pp. 1-8.

Teddlie, C. and Tashakkori, A. (2003), Major issues and controversies in the use of mixed methods in the social and behavioral sciences. In A. Tashakkori C. Teddlie (Eds.*), Handbook of mixed methods in social and* behavioural *research* (pp. 3-50). Thousand Oaks, CA: Sage

Teddlie, C. And Yu, F. (2007), "Mixed Methods Sampling: A Typology with Examples", *Journal of Mixed methods Research*, Vol. 1 No. 2007, pp.76-100

United Nations (2015), *Transforming Our World: The 2030 Agenda for Sustainable Development.* A/RES/70/1. The United Nations.

Urmila, B., Zisengwe, S., Meriggi, N., and Buysman, E. (2008), *Biogas Production in Climates with Long Cold Winter,* Wageningen University, The Netherlands.

USAID (United States Agency for International Development) (2006), *Collecting and Using Data for Impact Assessment,* Impact Assessment Primer Series No.3, USAID.

White, H. (2005), “Comment on Contributions Regarding the Impact of the Bangladesh Integrated Nutrition Project”, *Health Policy and Planning* Vol.20 No.6, pp. 408-41.

White, H. (2005), “Comment on Contributions Regarding the Impact of the Bangladesh Integrated Nutrition Project”, *Health Policy and Planning* Vol.20 No.6, pp. 408-411.

White, H. (2009), “Theory-Based Impact Evaluation: Principles and Practice”, *Journal of Development Effectiveness*, Vol. 1 No. 3, pp. 271-284.

Xiaohua, W. and Jingfei, L. (2005), “Influence of using household biogas digesters on household energy consumption in rural areas. A case study in Lianshui County in China”.