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# Institutional Factors Influencing the Dissemination of Biogas Technology in Ethiopia[1]

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**ABSTRACT** The dissemination of biogas technology was not progressing as it was planned in Ethiopia. Thus, this research aimed at identifying the institutional factors that influenced the dissemination of biogas technology. The study was a programme evaluation research type. The existence of less suitable institutional structure, the human resource gaps, user training gaps, maintenance service gaps, the supply and durability biogas digester accessories, the absence of biogas stove for baking *injera* and limited involvement of the private sector were identified to be the major obstacles for the dissemination of biogas technology. Therefore, among other things, the institutional structure should be increased to programme implementation *woreda* level. Standby biogas technicians who can give immediate maintenance services should be assigned at reasonable distances to the biogas adopters. Biogas being a new technology to farmers, provision of timely user training to each biogas user household involving women and children should not be compromised.

## INTRODUCTION

Energy is a key requirement to improve all aspects of human life. However, access to energy, particularly modern energy, has remained among the major challenges for most of the developing countries like Ethiopia. Ethiopia, despite its endowment with the huge potential of renewable energy sources, such as hydropower, wind, geothermal and biofuels, it still suffers from a severe domestic energy problem. According to International Energy Agency /IEA/ (2015), in the year 2013, the per capita energy consumption of Ethiopia was merely 0.51 tonnes of the oil equivalent (toe), while it was 0.67, 4.2 and 1.9 for Africa, Organization for Economic Cooperation and Development/OECD/ countries, and the world average, respectively. Moreover, as high as 93 percent of the population of Ethiopia relied on traditional biomass fuels for cooking, while it was 65 percent for Africa, 77 percent for sub-Saharan Africa and 39 percent for the world average (IEA 2011).

To address energy and related socio-economic and environmental challenges, the development and dissemination of domestic biogas plants emerges to be one of the promising areas of interventions, particularly in the rural part of Ethiopia. However, unlike emerging economies like China and India, where biogas technology is well-developed, the technology is still in its infant stage of development and dissemination in Ethiopia. Though the technology was introduced about five decades[1] ago into the country, the total number of biogas installations constructed prior to the establishment of the National Biogas Programme of Ethiopia (NBPE) was only about 1000 (Ethiopian Rural Energy Development and Promotion Center /EREDPC/ and the Netherlands Development Organization / SNV/ 2008; Yilma 2011).

The feasibility study on potentials of domestic biogas was conducted in 2006 by SNV-Ethiopia (Eshete et al. 2006). The study covered four major regional states, namely, Tigray, Amhara, Southern Nations nationalities and Peoples (SNNP), and Oromiya (Fig. 1) where over 70 percent of the human and about 70 percent of the livestock population of Ethiopia resides (EREDPC and SNV 2008). The study report estimated that the domestic biogas potential ranges between 1.1 million and 3.5 million households in the four regions alone. The report also proposed a five-year period pilot biogas programme in the

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four regions to the government (Eshete et al. 2006). Thus, on the basis of this proposal, the NBPE was established in 2008 (EREDPC and SNV 2008). The country envisaged developing a sustainable market-driven biogas sector and constructing 14 000 domestic biogas plants within the first phase (2009-2013) of the programme (Yilam 2011). It is now implementing its second phase (2014-2017) with the aim of building 20,000 additional biogas digesters (Kamp and Forn 2016). Nevertheless, in the first phase, to which this paper focused, the country was able to construct only 8063 (57.6 %) of its target set. Hence, for further improvement of the biogas programme and technology transfer, investigating the factors that influence the pace of biogas dissemination was believed to be a crucial area of research.

Much research has been done on the adoption and diffusion of household scale biogas technology (Gosens et al. 2013; He et al. 2013; Kabir et al. 2013; Mwirigi 2009; Mwirigi et al. 2014; Qu et al. 2013; Walekhwa et al. 2009). However, none of them provided an in-depth analysis on how the institutional factors influence dissemination of biogas technology. Specific to Ethiopia, biogas technology related research done so far in the country has focused on the operational status of biogas installations (Yilma 2011); a feasibility study of domestic biogas (Eshete et al. 2006); cost-benefit analysis of biogas technology (Gwavuya et al. 2012); factors affecting adoption of biogas technology (Mengistu et al. 2016); and overall barriers and drivers of biogas sector development and its further growth in Ethiopia (Kamp and Forn 2016). The last gave little attention to problems of beneficiary households and programme implementing wing at *woreda* level.

### Objective of the Study

The main objective of this research was to examine institutional factors that influence the dissemination of biogas technology in Ethiopia.

## METHODOLOGY

The study is a type of programme evaluation research which focused on programme implementation activities as factors influencing dissemination of biogas technology. It employed both primary and secondary data. Primary data were generated using a survey conducted from June 2013 to January 2014. Instruments of the survey were semi-structured questionnaires, key informant interviews, focus group discussions, and personal observation. Secondary data were collected from biogas Programme Implementation Document (PID) of Ethiopia, books, journals, magazines, office reports and records, and internet.

The semi-structured questionnaire was first translated into the local language. Next, it was pretested with 15 biogas adopter households in the real ground. This assisted in improving the language, removing ambiguity, and refining categories. Then the actual data collection was carried out in two purposefully selected sample *woredas*[2]. The sample *woredas*, namely, *Ofla* in Tigray Regional State and *Mecha* in Amahara Regional State (Fig. 1) were selected intentionally. Both *woredas* were the homes of the largest numbers of biogas installations in their respective regions during the survey time. Biogas adopter households who bought the technology earlier than a year were believed to have relatively better experience and familiarity with its benefits and drawbacks. Thus, rural households who adopted the technology earlier than a year were purposefully screened from the biogas adopter list and used as a sampling frame. There were 333 biogas adopter households in the sampling frame (235 in the *Ofla Woreda* and 98 in the *Mecha Woreda*). The sample size was determined to be 179, based on the general formula developed by Air University (2002). Then, using proportionate random sampling technique, 126 and 53 biogas adopter households were selected from *Ofla* and *Mecha Woredas*, respectively.

Key informants are individuals who are knowledgeable, open-minded, articulate, and cooperative for research interview purpose (Cole 2005; Neergaard 2007). In this research, a total of 45 key informants, who were supposed to provide research relevant information, were purposefully selected from various administrative levels.

For the study, eight focus group discussions, four per sample *woreda*, were held. To avoid the possible cultural influences on free discussions, separate groups were formed for two sexes. The optimum size for a focus group discussion ranged from six to eight members (Hennink 2007; Liamputtong 2011). Thus, two male and two female group discussions, having six or sev-

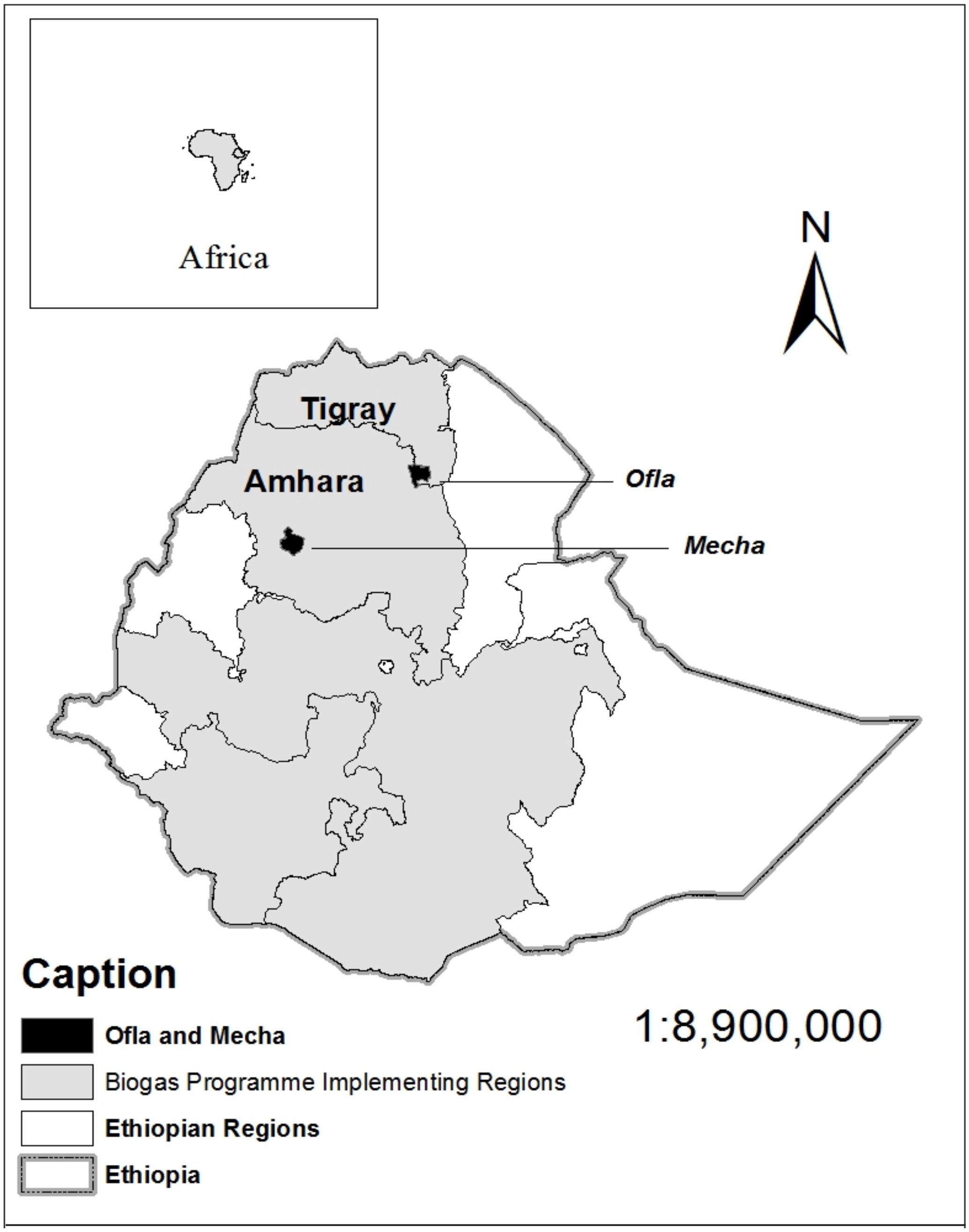


**Fig. 1. Location map of the surveyed woredas and biogas programme implementing regions**

en members per a group, were formed in each sample *woreda*. To ease, the task of bringing group discussants together, occasions of various social gatherings, such as religious gatherings, public meetings and public labour days, were exploited. Focus group discussion helped to gather information about problems of household energy in the area, barriers constraining biogas technology adoption among households, weaknesses of the biogas programme implementation, and suggested solutions to improve the programme.

Data analyses involved programme objectives and activity-based evaluation (Owen and Rogers 1999), and content and thematic analysis techniques. The major programme activities indicated in the PID included: promotion and marketing, training (users, promoters, and constructors), institutional support, quality management, research and development, and monitoring and evaluation.

## RESULTS AND DISCUSSION

### Institutional Factors

In this sub-section, prior to the analysis of institutional factors, the various conceptualizations of the term 'institution' were briefly reviewed and then an operational definition for the term was adapted. Next the institutional factors, namely, institutional structure, human resources, promotion and marketing, institutional supports (subsidies, manuals and guidelines, trainings, and maintenance services), supervision services, supplies of spare parts, monitoring and evaluation, and research and development were analyzed one by one.

To begin with the concept, the term 'institution' has been around and widely used over centuries (Hodgson 2006). However, there has not been full consensus among scholars on its definition (Aoki 2001; Hodgson 2006; Nelson and Sampat 2001). For instance, in everyday communications, the term institution is used to refer some well-known established organizations (Aoke 2001). In this case, the term institution seems to be synonymous with the concept of an organization. Contrary to this, North (1990) stated the existence of a conceptual difference between an institution and organization. Institution was defined as social rules or humanly developed constraints that dictate people's interactions, whereas organization was understood as actors or a group of people working towards attaining a common goal. Ostrom (2007) conceptualized institution as a variety of entities that encompasses organizations and rules controlling human interactions within and outside of organizations. Hodgson (2006) revealed that an organization is a special type of institution which is characterized by a) its own established criteria to delineate its boundaries or sphere of influence, and differentiate its members from non-members, b) principles of authority that specify accountability, and c) lines of command with defined responsibilities.

So there is a need to adapt an operational definition that best fits the purpose of analysis. Therefore, in this particular research, the term institution is taken to refer to Hodgson's special type of institution which has its own specific lines of commands with clear accountability, defined members and membership criteria, defined members' responsibilities, rules and regulations to be abided by all members, and clear objectives or goals to be achieved in specified time schedules.

### Institutional Structure

The institutional structure designed for the implementation of NBPE extends only from federal to regional administrative levels (Fig. 2). At federal level, under the Ministry of Water, Irrigation, and Electricity, there is Alternative Energy Technology Development and Promotion Directorate. Under this directorate, there comes a semi-autonomous office, NBPCO. The directorate performs regulatory activities and coordinates programme stakeholders. NBPCO carries out the daily routine coordination and programme management activities. In between the directorate and NBPCO, there is National Biogas Steering Committee (NBSC). It is composed of seniors from major biogas programme stakeholders. The Directorate's Director is the Chairperson and the NBPCO manager is the Secretary (EREDPC and SNV 2008). Since 2012, NBPCO has become directly accountable to the State Minister for the Ministry of Water and Energy (at the moment renamed as Ministry of Water, Irrigation, and Electricity), in order to empower the programme office better. Therefore, the current Chairperson for the NBSC is the State Minister.

The repeated structural change in the ministry to which the NBPCO belongs could have its own negative influence on the dissemination of the biogas technology. During the establishment of the biogas programme, the ministry was named Ministry of Mines and Energy, and then it was reshuffled to Ministry of Water and Energy, then after Ministry of Water, Irrigation and Energy, and now Ministry of Water, Irrigation, and Electricity.

Based on key informant interview, the NBSC currently has only eleven members. In addition to the aforesaid Chairperson and the Secretary, the members include two senior energy experts from the Ministry, a representative from SNV-Ethiopia, a representative from Institute of Sustainable Development, a representative from Ministry of Finance and Economic Development, and heads of the regional Mines and Energy agencies from the four biogas programme implementing regions. Besides, as stipulated in the PID, a representative from the Ministry of Agriculture and Rural Development (currently the ministry has been divided into Ministry of Agriculture and Natural Resources Development and Ministry of Fisheries and Animals), a representative from Ministry of Health, a representative from Environmental Protection Authority (currently reformed into Ministry of Environment, Forestry and Climate Change), a representative from Micro-finance Institutions, and a representative from private sector was supposed to be there (EREDPC and SNV 2008). But because of their repeated absence, they were no longer regarded as members of the NBSC. However, these stakeholders were supposed to play key roles in development and dissemination of biogas technology. For example, the agricultural sector was supposed to manage and ensure proper utilization of bio-slurry. Involvement of Ministry of Health was supposed to follow up sanitation and proper constructions of shelters for biogas digester connected toilets. Concerning to the agricultural sector, Kamp and Forn (2016) indicated that the weak linkages between the biogas and agricultural sectors undermine the inter-sector cooperation.

The NBSC is responsible for setting an overall direction to the development of biogas sector and providing advices on various biogas related matters, such as policy, annual plans, se-

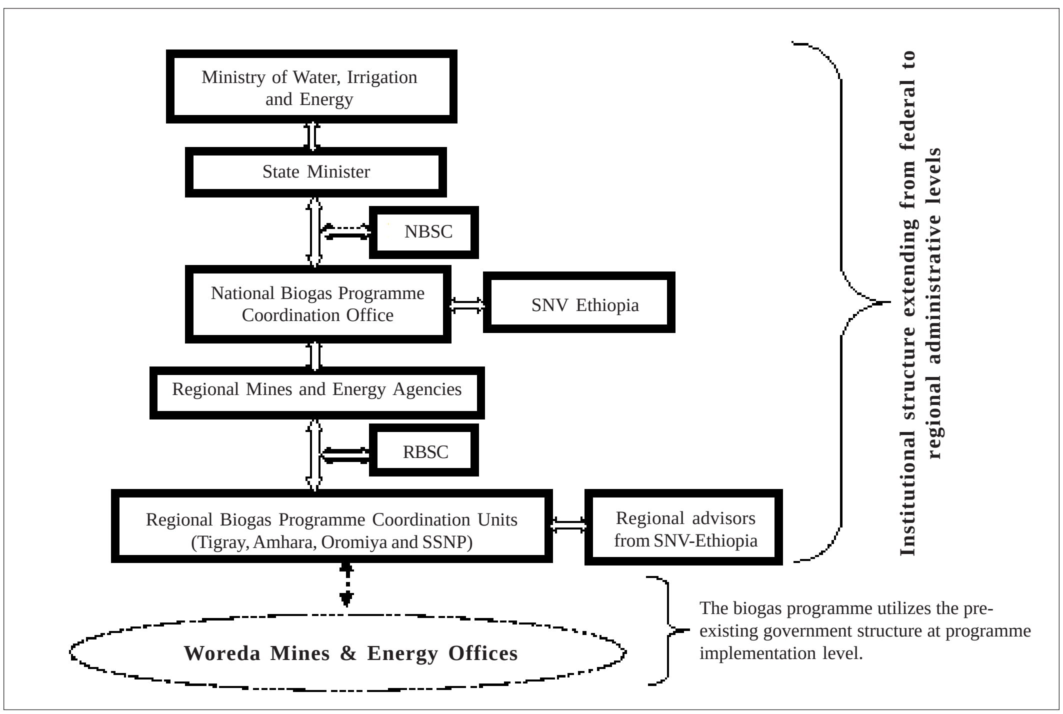


**Fig. 2. Institutional structure for the National Biogas Programme of Ethiopia**

lecting partner organizations, links with donors, quality standards and guides, and programme evaluation. It is supposed to arrange regular meetings twice a year or more when the need arises (EREDPC and SNV 2008). However, interview with some of the committee members indicated that the committee rarely meets as per the schedule. It has never been involved in programme evaluation in the field. Indeed, it was pointed out that whenever the committee meets, it forwards valuable ideas for the improvement of the programme.

Thus, the NBPCO carries out its duties under NBSC. The programme office gets technical and advisory support from SNV-Ethiopia. SNV-Ethiopia, as its roles preset in PID (EREDPC and SNV 2008), provides various capacity building services, such as training, technical advices, networking, and partnership building services to both NBPCO and its regional branches. Kamp and Forn (2016) also stated that SNV has been working as a technical advisor and promoter of the biogas programme of Ethiopia from the start.

At the regional administrative level, mines and energy agencies are in charge of regulatory issues and guardians of the programme. Under the regional energy agencies, there is also Regional Biogas Steering Committee (RBSC). The committee is composed of a representative from Mines and Energy Agency (chair person), the Regional Biogas Programme Coordination Unit (RBPCU) manager (secretary), a representative from Bureau of Finance and Economic Development, a representative from non-government organizations working in the region, a representative from regional Micro-Finance Institutions, a representative from biogas stove manufacturers, and a rural households' union representative. This steering committee is supposed to carry out similar tasks as that of the national committee (EREDPC and SNV 2008). The problem lies with its functionality. Ninety percent of the regional level key informants indicated that the committee was not as such active. In any case, under this RBSC, RBPCU performs the routine coordination activities including operational and financial management aspects of the programme.

Below the regional administrative level, only the Mines and Energy sector has increased its institutional structure to the *woreda* administrative level. Even this Mines and Energy sector is organized under the *woreda's* office of Agriculture and Rural Development. To realize implementation of the biogas programme, the RBPCU utilizes *woreda* mines and energy personnel as focal persons. Thus, *woreda* mines and energy office is acting as the extension of the biogas institutional structure and delivers programme implementation activities. Besides, whenever the RBPCU plans to start programme implementation in a new *woreda*, awareness raising workshops about the technology and the mode of dissemination are known to be given. It was indicated that the workshops involve *woreda* administration cabinet members. The cabinet members include heads of sector offices, *woreda* mines and energy personnel, development agents and rural *kebele* leaders. The cabinet members were labeled as *woreda*-level biogas sector steering committee, also known as *woreda* multi-stakeholder platform members. The *Woreda* Administrator is the Chairperson and the head of the *Woreda* Water Resources office is the Secretary. The *Woreda* Mines and Energy office is under the *Woreda* Water Resources office.

Nevertheless, the biogas steering committee was not that much functional at the *woreda* level either. The key informants mentioned two basic reasons for this. First, at *woreda* administrative level, there are always peak time or governing seasonal tasks done in campaign such as soil and water conservation campaign, parasitic insect elimination campaign, rural road construction campaign, fertilizer and better seed distribution season. The seasonal tasks made the cabinet members busy in organizing and leading the campaigns. Secondly, the cabinet members' were changed frequently. Therefore, even if biogas was discussed as a single component of the various *woreda* issues among the cabinet members, there is always the tendency of 'Let's hear from the horse's mouth'. The members could say almost nothing about the programme and the technology because they were not involved in monitoring and evaluation aspects.

Hence, it is the focal persons of the *woreda* Mines and Energy office that shoulder nearly the entire burden of implementation of the programme. However, the implementing wing of this programme could not be as effective as it was planned, for at least two reasons. First, in the institutional structure of *woreda* mines and energy sector, there are only two employees, namely, one coordinator and one energy expert. They are responsible for the implementation of all programmes related to mines and energy of any type and report to the higher administrative hierarchy. So it is automatic to see implementation of biogas programme as a single component of the diverse mines and energy related duties carried out in the *woreda* sub-sector. Even in some cases, the heads of the *woreda* water resources offices may assign one of the two biogas programme focal persons to the water resource projects (irrigation projects) as observed in *Ofla Woreda*. Secondly, the regional biogas programme coordinating units do not have a direct ‘chain of command’ or regulatory power over the *woreda* focal persons. Thus, upon problem of programme implementation in the *woreda*, the only option for the regional biogas programme coordinating units is to report the case to the regional mines and energy agency. Hence, it is likely for a problem of programme implementation to be delayed for some days, weeks or even months, before getting corrective legal measures. In this regard, Kamp and Forn (2016) pointed out the existence of frequent negotiation between RBPCU and *woreda* administration due to the latter commonly assigns the focal personnel to tasks non-exclusive to biogas.

Key informants at various administrative levels were asked whether the existing institutional structure is suitable to the development and dissemination of biogas technology. The majority (84.6 %) of the informants at national and regional levels believed that the institutional structure had to be expanded to programme implementation *woreda* level. The programme implementation level was indicated to be weakly organized for two reasons: existence of human resource gap and the indirect ‘chain of command between *woreda* mines and energy office and the RBPCU.

## Human Resources

Adequate size and quality of human resource is a prerequisite for the successful implementation of biogas programme. However, the overall full-time staff size of the biogas programme in Ethiopia is sixty-two. At NBPCO, there are only eleven staff members: five technical and six supportive staff. The staff include: 1) a programme coordinator; 2) two chief biogas engineers; 3) a database manager; 4) a planning, monitoring and evaluation officer; 5) a general service provider (purchasing and logistics); 6) a finance and administration officer; 7) a secretary and cashier; 8) a messenger and cleaner; and 9) two drivers. Even the second biogas engineer and a planning, monitoring and evaluation officer were added in the staff in 2012.

The chief biogas engineers are supposed to be involved in the development of quality control standards, development of programme strategies, and development and provision of training. According to key informants, during the first one or two years of programme implementation, when various training and workshops were urgently needed in all four biogas programme implementing regions, the size of technical staff, particularly the number of chief engineers, was too small to give efficient service. This can be evidenced from the very low numbers of biogas installations in the first two year of programme implementation period. The numbers of biogas plants constructed in 2009, 2010, 2011, 2012 and 2013 were 30, 731, 1643, 2509, and 3150, respectively. The planning, monitoring, and evaluation officer was rarely involved in monitoring and evaluation in the field, due to work burden at the office. Besides, as described in Rupf et al. (2015) shortage of technical biogas staff can also lead to inadequate training and follow up. The low functioning rates of biogas system in Sub-Saharan Africa are due to inadequate training and follow and lack of technical biogas skills specifically rural areas.

In the RBPCU, there are also both technical and supportive staff members. The technical staff encompasses: 1) programme coordinators (one for each region); 2) chief biogas engineers (one for each region); 3) promotion and marketing officers (one for each region); 4) bio-slurry extension officers (one for each region); and 5) twelve biogas technicians (three for each region).

The regional chief biogas engineers assist the national chief biogas engineers in developing quality control standards, programme strategies, and training, as well as providing technical advisory services to the biogas technicians. Regional promotion and marketing officers engage in planning how and when to use various promotion and marketing tools, distribute manuals and pamphlets, and coordinate stakeholders participating in biogas promotion and marketing activities. The biogas technicians deliver various construction materials, like dome pipes, PVC pipes and appliances to *woredas* and training masons, following up on biogas construction, and carry out quality control supervision on a sample basis. Bio-slurry extension officers coordinate all bio-slurry related extension services and trainings.

Given the large number of biogas programme implementing *woredas* and rural *kebeles* in each region, the long distance between regional office and each *woreda* and rural *kebeles* in each region, and the presence of only one or two focal persons at *woreda* level even without a direct 'chain of command with the regional office', the size of technical staff at the regional administrative level is also low. For instance, in Tigray and Amhara Regional States, there were 27 and 33 biogas programme implementing *woredas*, respectively, and hundreds of rural *kebeles* in a region. Hence, three biogas technicians in a region were supposed to deliver their intended professional services to all these *woredas* and rural *kebeles*. As the key informant interviews revealed, the biogas technicians were supposed to work in the field for 75 percent of the weeks in a month. Therefore, distributing biogas appliances and other biogas construction materials to *woredas*, giving technical assistances, making quality control visits on regular basis and travelling long distances from the regional office to various *woredas*, including the remotest ones, seems ineffective.

All key informants at both *woreda* and regional administrative levels revealed the existence of serious human resources gaps at implementation level (*woreda* level). Here, it should be noted that in the absence of institutional structure for biogas programme, talking about human resource at *woreda* level may seem strange but it refers to the *woreda* focal person(s). If the human resource gap at *woreda* level is solved, the existing staff size at regional level could be adequate. Author's observation in Tigray Regional State, *Ofla Woerda*, showed that because there is only a single individual in the *woreda's* Mines and Energy Office, it was the regional biogas technicians who paid money to the masons, after checking the quality and completion of the biogas construction on a sample basis. It is therefore unlikely that these biogas technicians will have sufficient time to effectively get involved in other duties, such as after-sale supervisions. Similarly, Bensah and Brew-Hammond (2010) revealed that the lack of skilled human resources that follow up the biogas installations is likely to be number one cause to the non-functioning of the biogas plants in Ghana. Thus, the human resources gap at programme implementation level needs due consideration.

**Promotion and Marketing**

According to regional biogas promotion and marketing officers, the biogas sector employed various promotion tools: electronic media (radio, television, and documentary films), printed materials (user manuals, calendar posters and pamphlets), and door-to-door promotion (words of mouth). However, the most effective and frequently used type of biogas technology promotion tool is door-to-door promotion. In support of this, 81.6 percent of the respondents indicated that orientation was their first and major source of information, and for 10.6 percent it was their neighbors and friends. In door-to-door biogas promotion type, *woreda* mines and energy personnel, development agents, rural *kebele* administrators, masons as well as biogas users were known to be involved. For each biogas installation, there is 5.13 $[3] incentive to be given to the one who convinced the potential adopter to buy and use the technology. This incentive was believed to be the primary reason that made the tool being the most effective one. Nevertheless, equal attention should also be given to the functioning status of the already installed biogas plants. Words-of-mouth from the satisfied biogas users can serve as a vital promoter of the technology (Gitonga 1997).

**Institutional Supports**

***Subsidies and Credit Arrangements***

The NBPE allocated a flat rate financial subsidy (256.25 $) given in kind per biogas installation, irrespective of the variations in digester size, location, inflation, and income status. With regard to the need for allocation of subsidy, it was pointed out that high initial investment cost of biogas technology has remained a principal obstacle for adoption and widespread use of the technology by the rural households (Arthur et al. 2011; Bensah and Brew-Hammond 2010). Hence, provision of financial incentives such as soft loans and subsidies are among the recommendations made for the success of biogas technology dissemination programmes (Winrock International 2007).

The subsidy was devoted first to cover predetermined rate of payment for masons, and then the remaining money was used to purchase biogas appliances and other construction inputs until the subsidy is used up. However, frequent fluctuations, mostly incremental, of the prices of various biogas construction materials, such as cement, biogas appliances and PVC pipe, have posed their own negative repercussions on the dissemination of biogas technology for at least two reasons. First, as clearly indicated in the PID under risk assumptions (EREDPC and SNV 2008), continual rise of prices of biogas construction materials definitely increases the technology's initial investment cost and reduces its affordability and hence, adoption and dissemination. Secondly, it creates suspicion among biogas adopters as to whether the government subsidy is being received in its entirety. In a difference of a few days or weeks in the adoption of biogas technology, households are requested to pay various amounts of money for differences between prices of the total purchases and the subsidy. The problem is particularly related to cement which cannot be purchased in bulk and stored over a year.

As indicated earlier, arrangement of soft loans is another mechanism that assists in reducing the backlash effects of high initial investment costs on biogas dissemination. As pointed out in the PID, microfinance institutions were supposed to be participating in the provision of credit for biogas construction (EREDPC and SNV 2008). However, according to key informants at national and regional administrative levels, micro-finance institutions particularly in Tigray and Amhara Regional States showed less interest in providing credits for financing biogas constructions for various reasons. The reasons included: 1) having rules to provide loans on immediate profit-making jobs while biogas is not such type; 2) fearing repayment problem; 3) having less encouraging information on operational rates of biogas installations; and 4) believing in the need to prepare special regulation for biogas loans. In contrast to this Kamp and Forn (2016) reported the gradual integration of the micro-finance institutions to the NBPE. Besides, it has also been reported that as high as 57 percent of the biogas installations that were built by the NBPE utilized loans from the microfinance institutions in funding the initial investment of the technology. This might be true in other biogas programme implementing regions (Oromiya and SNNP). But the percent indicated is still doubtful. As indicated earlier, due to their less interest in providing loans to the biogas installations, microfinance institutions were not members to the biogas programme steering committee at both federal and surveyed regional states. Among the sample biogas households, only 5 (2.8 %) of the biogas adopters reported using loans from microfinance institutions in financing their biogas installations.

That is way the regional government in Tigray designed its own solution and provided cement and PVC pipes on credit through farmers' cooperatives to all biogas adopters, to be repaid over three years. This credit scheme helped the region to increase the uptake of biogas technology, compared to the SNNP and Amhara Regions. During the programme period, the total biogas installations in Tigray were 1992, Amhara 1892, SNNP 1699, and Oromiya 2480. In Amhara Regional State, it was stated that farmers who are members of the farmers' cooperatives can take credit for biogas construction through the cooperatives.

### *Manuals and User Guidelines*

For the success of biogas programme implementation, various manuals, guidelines, pamphlets, and calendar posters were prepared. The manuals and guidelines prepared by the NBPE included: 1) construction manual; 2) quality control standards and formats; and 3) biogas utilization guideline. In Cambodia too, manuals for biogas users on how to operate, make maintenance, and use bio-slurry; manuals for masons; and manuals for programme office managers were indicated to be prepared and used (Buysman and Mol 2013).

It is clear that the availability of detail user guideline contribute a lot to the long-lasting utilization and continuous operation of the biogas system. However, the distribution of these user guides which could be used as references in case of doubts or difficulties in operating or maintaining the biogas system were very much limited. Among the surveyed biogas households, about 82 (45.8 %) did not get any written material on biogas. More specifically, 38 (71.7 %) of the sample households in *Mecha Woreda* and 44 (34.9 %) in *Ofla Woreda* did not obtain user guideline. In the absence of a reference material, biogas adopters may fail to operate or maintain the biogas system and may make the potential clients retreat from its adoption. Nevertheless, the biogas households had the potential to utilize the user manuals effectively. This is because 150 (83.8 %) of the surveyed biogas household heads had a minimum of reading and writing skills. Even among those 29 (16.2 %) illiterate household heads, 27 (93.1 %) had at least one educated family member with a grade 5 or higher level of education. Hence, a detail user guidelines written in local language, comprising step-by-step techniques of operating and maintaining the biogas plant, having pictorial depiction and principles of do's and don'ts, should either be provided to all users timely or presented at a reasonable price.

**Training**

For successful implementation of a new programme involving new technology and new approach, the provision of training is a key requirement (EREDPC and SNV 2008). Consequently, diverse training, such as mason training, biogas users' training on how to operate and do minor maintenance, bio-slurry utilization training, supervisor training, refresher training for masons and supervisors, and biogas technician training were given to the different groups of actors involved in the implementation of NBPE.

Mason training was seen as a priority requirement for the implementation of the programme (EREDPC and SNV 2008). Thus, a total of 1022 biogas masons with previous masonry or plumbing experiences were screened, trained, and certified in the programme period. Although the plan was to develop 20 private biogas construction enterprises in the programme period, the key informants revealed the absence of any enterprise created in the period. Kamp and Forn (2016) also stated that the duty of creating private biogas sector that was unaccomplished during the first phase of NBPE has been a vital goal to the second phase of the NBPE.

Measuring the skill of the masons and effectiveness of the trainings offered definitely need independent research. However, the skill of the masons can be reflected in the quality of the biogas installations. In this respect, the surveyed biogas adopters were asked whether the masons were skilled in constructing the biogas plants. Accordingly, 154 (86 %) of the respondents said they were skilled while the remaining 25 (14 %) said not skilled. The justifications given by the latter incorporate the following: 1) cracking of domes and cracking and/or fracturing of inlet pits, outlet tanks, and slabs that results from the use of impure sand and incorrect cement-sand ratio; 2) bio-slurry outflow before fermenting and inflow of bio-slurry back to the digester; 3) failure to function after the completion of construction and being unable to identify the problems; 4) improper plumber work and problem of gas leakage; 5) the inability to make it functional, after doing the laborious task of emptying and plastering digesters; 6) improper orientation given to the biogas adopter to feed one's biogas digester as much input as one full of inlet pit everyday and the plant failed to operate as a result; and 7) improper site selection, where either the bio-slurry flows to neighbors' yards or digesters are installed in front of the houses, which make them difficult to use biogas digester-connected toilets.

A problem like the use of impure sand could be the result of carelessness and irresponsibility. Other problems such as the outflow of bio-slurry before fermenting, the improper ratio of cement and sand, and failing to identify where the problems lie could be the result of skill gaps in taking measurements and other basic skills. Thus, masons with such irresponsible behavior or skill gaps should be identified as early as possible before ruining a number of biogas installations through establishing communication network with biogas adopters and closer follow-up and supervision.

Biogas user training is also an essential requirement that equips the farmers to be able to properly operate the biogas plants and resolve minor maintenance problems. As indicated in the PID, the plan was to provide user training twice during the pre- and post-construction periods (EREDPC and SNV 2008). However, with the exception of provision of a simple orientation/instruction for a few minutes (10-15') by masons and/or supervisors, biogas user training was neither given uniformly across all biogas implementing regions, nor to all biogas user households. In the Tigray Regional State, user training was given more often to three members of a biogas user household whereas in Amhara Regional State it was given only to a single household member, mostly to the head. So in a culture where women and children are almost exclusively responsible for cooking, provision of user training to household heads, dominantly males, definitely contributes little to the proper and sustainable utilization of the biogas plants. The budget for user training was known to be given on unit biogas installation basis. As key informant revealed, the problem with the provision of user training at the right time was associated with the matter of commitment at the Regional Mines and Energy Agency and the Regional Biogas Programme Coordination Unit.

In addition, 61 (34.1 %) of all the surveyed households did not get user training. Indeed, provision of user training was quite better in Tigray Regional State than in Amhara. Among 126 surveyed biogas households in *Ofla Woreda*, Tigray Region, only 30 (23.8 %) households did not get user training. Whereas, in *Mecha Woreda*, Amhara Region, of the 53 surveyed biogas households, as high as 31 (58.5 %) did not get any user training.

Moreover, of the total biogas adopter sample households, only 11 (6.1 %) of them got both the pre- and post-construction user trainings. Nevertheless, provision of these planned user training types at the right time are critically important for sustaining utilization of the biogas plants at least as further in time as the presupposed service years of the technology. Buysman and Mol (2013) also stated that the provision of both pre- and post-construction biogas user trainings assist the users to maximize benefits and satisfactions.

Provision of trainings on utilization of bioslurry was also lacking the necessary attention. One of the main reasons for this could be lack of belongingness on the part of the agricultural sector towards the biogas programme or the biogas projects. Most likely, this tendency came as a result of the non-involvement of the sector during biogas programme development. At the initial stage, more attention was given to the energy benefit aspects of biogas technology. The agricultural sector was not involved in the preparation of the PID (EREDPC and SNV 2008). Besides, the sector was not regarded as a member of the regional biogas steering committee. As a result, the bio-slurry extension component of the biogas programme was not given to be led and guided under the sector's institutional structure. So this should also be reconsidered. Otherwise, the existing regional bio-slurry extension component of the RBPCU would remain nominal and inactive.

Therefore, apart from the regular duty of promoting compost preparation and utilization to the entire public, no special attention was given to bio-slurry utilization and training on the same in the sector. Even as observed in *Ofla Woreda*, there seemed be a conflict of interest between biogas programme unit and agricultural and rural development office. In the Growth and Transformation Plan (GTP), there was a target to boost up smallholder-farmers' productivity to about twofold by the end of the plan period (2010/11-2014/15) (FDRE 2010). In connection with this grand plan, in *Ofla Woreda*, the agricultural and rural development office compel every household who own farmland to buy at least a predetermined minimum amount of chemical fertilizer. The amount is proportional to the size of farmland ownership. This situation interferes with promotion of bio-slurry use and discourages biogas owners who effectively utilize bio-slurry for fertilizer.

The Institute of Sustainable Development (ISD), local non-governmental organization, provided bio-slurry training to about 800 biogas users in all the four biogas programme implementing regions. The interviewee indicated that the trainings focused on model and influential farmers so that knowledge and experiences were believed to be shared among biogas users. Kamp and Forn (2016) also indicated the participation of ISD in user training on the utilization of bio-slurry.

**Maintenance Services**

Absence of follow up and maintenance service was one of the major problems identified for the failures of many of the biogas installations constructed prior to the establishment of NBPE (Eshete et al. 2006; EREDPC and SNV 2008). So to solve this problem in the newly-established NBPE, quality management was designed to be one of the basic programme activities. Quality management, as indicated in the PID, comprises control of construction qualities and maintenance service (EREDPC and SNV 2008). In the 15-point tri-party agreement among biogas adopter, mason, and the programme agency, the mason was required to give a two-year guarantee for the structural part and a one-year guarantee for appliances and pipelines. One of the enforcement mechanisms designed for this purpose was withholding 10.25 $ from the total subsidy so as to be given to the mason after two years of free maintenance services upon the approval of the users for the service gained.

However, maintenance service was not given as expected for the following reasons. First, though it was the masons who signed the aforesaid tri-party agreement, some masons give the duty of fitting biogas pipelines to plumbers agreeing to pay them 5.13-10.25 $. This was because masons with previous plumber work experiences tend to work on fittings while masons with previous masonry experiences tend to work on the structural parts of the biogas plants. Actually, it is good for the biogas pipelines to be fitted by experienced plumbers. But at the same time, it is this part of the biogas plant that needs repeated maintenance services. Whenever the biogas plant develops problems in any part of the pipeline, the plumbers were not willing to give maintenance service whereas the masons in some cases failed to identify and solve the problem. It may be this skill gap that made some masons to give pipeline fitting duties to plumbers. Even in conditions where the masons did the entire cement and pipelines work, the masons more often did not give immediate maintenance services as they were busy in constructing new biogas plants in further rural *kebeles*. In this regard, a regional advisor from SNV-Ethiopia revealed that masons have not yet seen the construction of biogas plants as a business. As a result, they do not visit biogas plants after the completion of construction. In this regard, Bensah and Brew-Hammond (2010) stated that lack of skillful attendants of the biogas installations is likely to be number one factor that contributes to the failures of biogas projects in Ghana. In fact, mention also has to be made of the positive social relations created between some masons and the biogas adopters which morally compel the masons to give maintenance service at any cost of time and distance.

Second, greater attention seems to be given to the number of biogas installations. In free-grazing system where cattle are roving during the day time, it was recommended that a minimum of four heads of cattle would be able to effectively feed a domestic biogas plant with a 4 $m^3$ digester size (EREDPC and SNV 2008). However, when the sample biogas adopters were asked whether there was change in size of cattle following biogas adoption, it was found that a biogas household started with a single head of cattle in *Ofla Woreda*. The reason given was that being a *kebele* female representative, she was supposed to help in promotion activities. Besides, all the surveyed biogas digesters in *Ofla Woreda* were 6 $m^3$ in size. But normally households were expected to have a minimum of four heads cattle which is below the standard indicated. Besides, the *woreda* focal persons were given around 25.63 $ per biogas installation. So it is more likely to push the masons to finish a biogas installation within 15 days as per their commitment indicated in the tri-party agreement. Here, this is not to criticize the incentives given, but it is to say incentives should be as per the number of functioning biogas plants too. By examining the ambitious yearly forecast and actual number of biogas installations, Kamp and Forn (2016) also reported the existence of higher interest in the number of biogas plants in Ethiopia.

Third, withholding 10.25 $ as an enforcement mechanism is too small to morally attract the masons given dispersed locations of biogas plants and frequent operation problems resulting from lack of user training. Fourth, despite the tri-party agreement, there was no practical legal enforcement mechanism to compel masons to give timely maintenance service. This was evidenced by the fact that some masons left the construction of biogas plants before finishing, for financial reasons. As a result, some biogas plants remained incomplete for one or more years. The payment for masons varies from 123 $ to 146.1 $ depending on digester size and distances.

A question was raised to supervisors and programme coordinators about the measures taken in such circumstances. They revealed that though they explained the possibility to take the case to the courts, they didn't do that due to shortage of manpower to follow up the cases. Instead, they explained payments to masons were given according to the stage of construction progress. So if a mason fled away at certain stage, the mason could easily be substituted by another mason and the payment for the remaining construction stages could be shifted. This progressive payment is also mentioned in the tri-party agreement. However, the surveyed incomplete biogas plants remained unfinished for 14 to 24 months. One possible reason for this could be progressive payments were not put into practice. Therefore, for a variety of reasons, of the total 179 surveyed biogas plants, 129 (72.1 %) of them were operating where as the remaining 50 (27.9 %) were not operating. Of the 129 functioning biogas plants, only 96 (74.4 %) of them have both functioning stoves and biogas lamps whereas the rest have either functioning stoves or biogas lamps. Thus, of the total surveyed biogas plants, only 53.6 % had fully-functioning stoves and lamps. But in PID it was targeted to maintain the rate of functioning more than 90 percent (EREDPC and SNV 2008). The problems with non-functioning biogas plants included: 1) problems on pipelines (leakages, loosen valves, blockage by bio-slurry); 2) cracking of domes; 3) incompleteness from the beginning due to masons fled away; 4) shortage of appliances; 5) demolished by task force due construction on illegal sites (*Ofla Woreda*); 6) biogas adopters own problems; 7) improper site selection (bio-slurry flows to neighbor); 8) flow of bio-slurry before fermenting; 9) backflow of bio-slurry to the outlet tank; and 10) over-feeding.

The respondents were asked about the efforts made to get maintenance services. Thus, the responses included: 1) applied many times but obtained no more than lip service [22 (44 %)]; 2) tried nothing [12 (24 %)]; 3) masons and/or supervisors came but unable to repair [4 (8 %)]; and 4) repaired but failed to operate again [2 (4 %)]. In the absence of standby personnel who can give maintenance service, there may be delays for several days or weeks until masons working in further rural areas arrange their convenient time. Ghimire (2013) also mentioned that upholding maintenance service is one of the key challenges of biogas programmes in Asia and Africa. One of the main reasons for the non-functioning of 28 percent of the surveyed biogas plants in Ghana was lack of maintenance service (Bensah and Brew-Hammond 2010).

Despite the better trainings given, the problem of maintenance services was found to be more serious in the *Ofla Woreda* than in *Mecha*. Out of the total 50 surveyed non- operating biogas plants, 43 were found in *Ofla Woreda*. Nine out of forty-three non-operating biogas plants remained incomplete for 14 to 24 months in *Ofla Woreda*. One of the major justifications for this could be the absence of follow-up. There is only one focal person in the woreda. The same is true in ensuring the existence of maintenance service. Therefore, the problem of maintenance service needs urgent action. Focus group discussants also emphasized on three issues for immediate improvement in the programme: maintenance service, user training, and availability of spare parts. Hence, one solution may be to assign a standby biogas technician who can give immediate maintenance and advisory services in each *woreda*. The other solution, which is even more cost-effective, could be the provision of on-the-spot intensive maintenance training to a few, may be three, educated, wise, and committed farmers per rural *kebele*. In support of the latter, mentioning a specific case may be very helpful. In *Mecha Woreda*, a biogas owner requested about the existence of maintenance service. He had a blockage of the pipeline and asked the mason for maintenance service. While the mason was repairing, he attentively followed how the mason did repair and observed the necessary tools for repairing. Then afterwards, he repaired not only his own but neighboring biogas plants too. He was asked how he was able to learn how to repair in such a short time and he replied that he had grain mill and carried out some minor maintenance on it.

**Supervision Services**

Closer supervision and follow up is quite essential to control quality of construction, verify adherence to the standardized design, confirm compliance of measurements to the standards set, check proper operation of the biogas installations, and entertain complaints on maintenance and other services. Accordingly, the NBPE prepared four types of quality control forms: quality control Stage One (QC1) and Stage Two (QC2) to be filled in by focal persons, construction completion quality control form (CCF) to be filled by regional biogas technicians, and 'after sales services' quality control form (ASS) to be filled by regional or federal supervisors. QC1 was expected to be filled before and during construction. Starting from site selection, planning, and layouts, QC1 helped to follow up the various stages of construction and check quality and sufficiency of construction materials presented. QC2 was filled immediately after completion of construction (MoWE 2010). The availability of these quality control forms clearly helps the supervisors to have in-depth supervisions. They help to cross-check whether all types of work are done right.

The surveyed biogas adopters were asked about how often supervisors visited their biogas plants after the completion of construction. Accordingly, 123 (68.7 %) of them replied they were visited at least once whereas the remaining 56 (31.3 %) said no supervisor came at all. Among the former, 34 (27.6 %) of the plants were visited once, 46 (37.4 %) visited twice, 24 (19.5 %) visited thrice, and the remaining 19 (15.4 %) visited four or more times. The latter were also asked the benefits they obtained from the supervisions. About 86 (69.9 %) of them replied they obtained advice, maintenance services, and motivation. The remaining 37 (30.1 %) said that they obtained nothing. It was also pointed out that supervisors mostly come without any maintenance tools. Hence, they can only maintain the type of problems requiring no maintenance tools.

In the PID, it was indicated that supervisions would be carried out on sample basis (EREDPC and SNV 2008). If this is so, the proportion of visited biogas plants could be quite enough. But supervisors seemed to be directed towards the operating ones. This is because the proportion of non-operating visited biogas plants [29 (58 %)] was greater than operating visited biogas plants [94 (72.9 %]. Hence, if supervision is not done on random basis, there will not be more chance for those non-operating biogas plants to get solutions. For instance, in *Ofla Woreda*, based on information obtained from the surveyed biogas owners and the survey itself, the entire seven biogas plants constructed in *Adishmbereket Tabiya (Kebele)* remained incomplete (four of them were among the surveyed ones). Had there been supervision on random sample basis, these biogas plants might get solution. Based on personal observation, in rural *kebeles*, where there were many non-operating biogas plants, such as *Adishmbereket* in the *Ofla Woreda* and *Bachima* in *Mecha Woreda*, there were no new uptakes at all. *Bachima Kebele* was the first *kebele* where domestic biogas was introduced in *Mecha Woreda*. Unfortunately, as informants indicated, because of improper sand type used for construction, six out of eight biogas plants failed to function.

**Supplies of Spare Parts**

Availability of biogas spare parts within reasonable distance is a decisive factor for dissemination of biogas technology. Spare parts of biogas technology that are used in common as spare parts of pipe water installations and other constructions are widely available in the market. Those spare parts which are used solely for biogas technology are not available as needed. Biogas stoves have started to be produced by private manufacturers in the regional capitals. For example Walta Workshop in Mekele Town and Munic Engineering Plc in Bahir Dar Town have stated producing biogas stoves. After attending workshops at the Selam Technical and Vocation Training Centre in Addis Ababa and given the required biogas stove model by NBPE, they are now producing and selling biogas stoves when ordered. They also produce and sell reducers, dome pipes, and templates. Even the efficiency of the stoves produced in Ethiopia (46.4%) are reported be much less efficient than India or China (60%) (Khandelwal and Gupta 2009). But biogas lamp and all its accessories and pressure gauges are imported by the government.

Two basic problems were raised by group discussants with regard to spare parts particularly biogas lamp glasses and mantles. First, the spare parts are not available all times at the *woreda* offices. So farmers were requested to wait until they come from the regional or federal offices. Second, sometimes the *woreda* offices are closed for field or other reasons. For those farmers coming from the remotest parts of the *woreda*, it is very tiring. In *Ofla Woreda*, due to the shortage of the right biogas mantle types, biogas users commonly buy and use mantles originally meant for kerosene lamps. These mantles purchased from shops were indicated to be less durable as compared to the ones given at the *woreda* office. Thus, owing to shortages of spare part only, operation of 7 (3.9 %) of the surveyed biogas plants were interrupted. Key informants at various administrative offices admitted the existence of spare part supply problems in the first two years of programme implementation. But the problems were indicated to be solved afterwards. Even it was pointed out that the spare parts were given freely at the *woreda* offices. However, in reality, may be because of the problem of distribution or failure to request for the spare parts from the regional or federal offices at the right time, there were complaints about the shortages of supplies of spare parts. Wondyfraw (2015) also reported the existence of inadequate supply of spare parts.

Therefore, instead of even giving the spare parts freely but demanding farmers to travel long distances to the *woreda* offices, it would be better to put the spare parts at each rural *kebele* office and sell them at reasonable prices. Especially during peak cropping seasons, farmers may not have enough time to travel a long distance to the *woreda* offices to get spare parts. Besides, sometimes they may find offices closed and the other times there may be a temporary unavailability of spare parts.

## Monitoring and Evaluation

Monitoring and evaluation was also planned to be carried out in the programme period. Monitoring the overall progress of the programme was supposed to be carried out by EREDPC (now named Alternative Energy Technology Development and Promotion Directorate). The daily monitoring was intended to be done by NBPCO and RBPCU. Two types of evaluation were mentioned: internal or external ones. External valuation was planned to be done twice in the programme period by external consultants (EREDPC and SNV 2008). However, only the mid-term review was conducted in August and September 2011 by an external consultant recruited by the African Biogas Partnership Programme. The mid-term review had three focus areas. The first focus area was to determine the status of the programme in terms of four dimensions: expectations, efficiency, efficacy, and partnership mapping. It was presented by the National Biogas Programme Office of Ethiopia. The second area was programme implementation assessment using strength, weakness, opportunity, and threat (SWOT) analysis system. It was done in the workshop that involved programme stakeholders. The third area was to evaluate whether the programme was developing towards sustainability in relation to market development, enabling economic environment, and responsive policy. So the mid-term review was a workshop-based assessment. Moreover, as a component monitoring and evaluation, user survey was also planned to be conducted annually. However, there wasn't any done so far. Hence, the numbers of operating and non-operating biogas plants were not known correctly at national level.

## Research and Development

Research and development is one of the major activities designed to be implemented in the national biogas programme. It is aimed at ameliorating programme implementation, reducing the costs of unit installations, and maximizing the benefits of the technology. For practical purposes, the activity's budget share and potential research areas were mentioned in the PID. The document also pointed out that capable research institutions, biogas companies, and consulting firms were supposed to be involved in research, monitoring and evaluation endeavors of the biogas programme (EREDPC and SNV 2008). Introducing thorough research and development and quality control components to the biogas programme assist to ensure that the supply side stakeholders provide full-fledged services to their customers (Ghimire 2013).

However, key informant interview with various individuals indicated the absence of well-coordinated research and development activities. Despite the existence of various research trials, both at private and institutional levels, they were fragmented and lacked continuity. For instance, institutionally there was an attempt to replace stones with interlocking soil blocks but this failed and was interrupted. In Amhara RBPCU, there was an attempt to develop a biogas lamp, but it was not developed further. An *injera* stove was also developed by a private researcher in Amhara Region and three *injera* stoves were given to farmers for piloting purpose. The stove enabled baking 23 *injeras* at a time, after saving gas for three days. However, the research has still continued for further improvement. In the Tigray Region, an *injera* stove and a clamp, a biogas lamp accessory, were also developed by Mesfin Industrial Engineering and Walta Workshop, respectively. But both technologies were not upgraded for consumption.

Thus, among the major bottle necks that retard adoption and dissemination of biogas technology include: 1) failure to use biogas technology for baking *injera;* and 2) short lifespan of biogas lamps, that is, the frequent breaking of biogas lamp glass and burning of mantle. Baking *injera* was estimated to be consuming about 5-0 percent of the total household energy consumption (Gebreegziabher 2007). Consequently, adoption and use of biogas technology has never fully replaced the utilization of traditional biomass fuels. The sample biogas adopters were asked what to be improved in the overall biogas programme of Ethiopia. Accordingly, as high as 124 (69.3 %) of the respondents suggested the need to introduce an *injera* stove that works with biogas. Focus group discussants also emphasized the need to introduce *injera* stove. Besides, improving durability of biogas lamps through research and development is a critical requirement for further dissemination of biogas technology. The frequent breaking of biogas lamp glass and burning of mantles, together with their unavailability on the local market, not only discourages the biogas users but also the potential adopters. As Buysman and Mol (2013) stated, convincing clients to adopt biogas technology in the presence failures is challenging.

## CONCLUSION

Dissemination of biogas technology was not progressing as it was planned in Ethiopia. The factors that stunted the pace of dissemination of the technology, among others, are institutional ones. The institutional structure for NBPE is found to be less suitable for smooth implementation of the programme. It extends only from federal to regional administrative levels. Programme implementation level is left to the pre-existing *woreda* level government structure. The *woreda* mines and energy office which is acting and serving as an extension of the biogas institutional structure was not suitably rearranged. 1) There is no a direct 'chain of command' between RBPCU and *woreda* mines and energy offices; and 2) there are only one or two employees in the *woreda* mines and energy office structure.

The biogas programme steering committee established at different administrative levels was found inactive. The members lacked commitment and even some important stakeholders, like the agricultural sector, were not involving at federal and regional level. The biogas programme has also a serious human resource shortage. The technical staff members particularly a single biogas engineer, three biogas technicians, and a single bio-slurry utilization expert (agronomist) in a region are few to give the required technical services.

Provision of subsidies and credit arrangements, the latter as seen in Tigray Region, were known to make a great contribution towards speeding up the dissemination of biogas technology. Indeed, the frequently rising of prices of biogas construction materials due to inflation were posing backlash effects on biogas dissemination and reduced real value of fixed and constant subsidy rate.

Biogas user training was neither given uniformly to all biogas adopter households nor across all biogas programme implementing regions. In Amhara Region, user training was given only to the head of biogas adopter household, dominantly men. Provision of training on utilization of bio-slurry also lacked the necessary attention. The involvement of the agricultural sector in this regard was found to be limited. Most of the biogas adopter households (more than 95 %) have either literate household heads or have at least one literate household. But biogas user guidelines were not provided uniformly.

As evidenced by problems like the cracking of domes, bio-slurry outflow before fermenting, failure to work right from the beginning and inability to identify the problems, and inability to solve the problem after ordering the laborious duty of emptying the digesters, some biogas masons lack basic biogas construction skills. Biogas users were not obtaining maintenance service regularly and immediately on demand. The enforcement mechanism is too weak for masons to give regular maintenance service. Therefore, for a variety of reasons, of the total surveyed households, 50 (27.9 %) were not operating at all, and 25 (14.0 %) had either non-operating stoves or biogas lamps.

Biogas spare parts, particularly biogas lamp and its accessories, were not available regularly and at a reasonable distance from the biogas users. However, due to frequent breakage of the biogas lamp glasses and burning of the mantles, these spare parts are demanded every time. The regular unavailability of these spare parts has a daunting effect on the further dissemination of biogas technology.

User survey has yet been conducted. Thus, the numbers of operating and non-operating biogas plants have not yet been known at national level. Research and development in the NBPE was found to be fragmented and lacked continuity. Despite the various attempts, there were no any concrete research and development results that reached to the public consumption level, during the programme period.

Given all the above constraining factors and the absence of biogas masons developed to biogas construction enterprise level, realizing the emergence of market driven biogas sector seems to take a long time and need an endless effort and commitment to resolve those constraints.

Finally, the research gaps that the author would like to suggest further studies include: measuring the skills of masons and effectiveness of trainings given; the relative advantages of bio-slurry fertilizer over that of chemical fertilizer, the conventional manure, and compost supported with practical demonstration over different agro-ecologies and soil types; the effect of transaction costs on biogas technology dissemination in rural Ethiopia.

## RECOMMENDATIONS

1. The institutional structure of the national biogas programme should be increased to the programme implementation level, *woreda* administration, with clear 'chain of command' and accountability.
2. The shortage of biogas engineers, biogas technicians, and agronomists should be resolved and standby biogas technicians, who can give immediate maintenance and advisory services, should be assigned at the earliest time possible.
3. To reduce the negative effect of inflation on fixed subsidy rate over programme period, subsidy size should be adjusted based on inflation rate scenario ranges from a given base year.
4. Biogas being a new technology to farmers, provision of timely user training to each biogas user household involving women and children should not be compromised.
5. A detail user guideline comprising step-by-step techniques of operating and maintaining the biogas plant with pictorial depictions and principles of do's and don'ts can augment user training and thus should be presented at least with reasonable price.
6. Biogas masons having basic skill gaps should be identified and corrected as early as possible through establishing communication network with biogas users and closer follow-up and supervision. Those skillful biogas masons who construct quality and properly functioning biogas installations should get reasonably attractive incentive that could retain them in the sector.
7. Biogas spare parts like biogas lamp and its accessories which are less durable and frequently demanded by the users should be purchased in bulk with revolving fund and be available regularly for sale at centers (rural *kebele* offices) that are reasonably near to the biogas users. It is also important to encourage local shops to include selling these items.
8. The NBPCO should also give due attention how words of mouth from the satisfied or dissatisfied biogas users can enhance or retard adoption of biogas technology. The office should also ensure the proper functioning of the already installed biogas plants through monitoring and evaluation services, establishing biogas technology maintenance service centers at reasonable distance, and assigning a standby biogas technology technician(s) for the centers so that biogas households can get immediate maintenance and aftersales services. To learn the number of operating and non-operating biogas plants, ensure whether the biogas adopters have gained the intended benefits of the biogas technology, identify the practical problems of the users, and formulate a successful plan to the future, conducting a national level user survey at a regular time should not be an optional in a biogas programme period.
9. Research and development should focus on cost reduction aspect of biogas technology, augmenting the technology's service through developing biogas stove for *injera* baking, and improving durability of biogas lamp and its accessories.

## NOTES

1. Though there are variations among authors as to the exact time when biogas was introduced into Ethiopia, it seems reasonable that it was Bekele who wrote that it was he himself who constructed the first biogas installation in 1962 at Ambo School of Agriculture, the later Ambo College of Agriculture (Bekele 1978).
2. *Woreda* is the second lowest administrative unit next to *kebele* in Ethiopia
3. United States Dollar ($) is based on January 2014, exchange rate with Ethiopian currency- Birr (1 Birr= 0.05125 $).

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