COMMUNITY INVOLVEMENT IN A LOW COST BIOGAS PLANT IN AN ANDEAN REGION

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Sommario

Lo scopo del presente lavoro è quello di investigare soluzioni tecnologiche sostenibili nel settore delle energie rinnovabili verso i paesi in via di sviluppo, dove la mancanza di risorse rappresenta una problematica sostanziale. Lo studio si concentra sul processo di produzione biogas attraverso impianti lowcost situati nella regione andina Apurimac, in Perù.

A completare questa analisi, è stato svolto uno studio di impatto sociale sulle comunità interessate valutando nel dettaglio il coinvolgimento di donne e bambini nella gestione dell'impianto, essendo infatti tale sistema considerato facente parte delle cosiddette "gender technologies", ovvero tecnologie in grado di promuovere la figura della donna nella comunità.

Abstract

The aim of the present paper is the investigation of suitable technological solutions in the field of renewable energies addressed to a developing country environment, where the lack of resources and means is a not negligible issue.

The study focuses on the development of biogas low-cost plants located in the Andean region of Apurimac.

A direct social impact on the community has been evaluated considering the working time and burden saving for women and children, belonging the biogas digester to a list of "gender technologies"[1], recognized as technology helping the improvement of women social and family status.

Keywords

Energy, biogas, Andean, comunity, technology

Introduction

The present work represents a deep investigation on suitable technological solutions in the field of renewable energies addressed to a developing country environment. Part of the work was made possible thanks to the collaboration between the University of Genoa and the association Apurimac Onlus, based in Rome.

In particular, the study focuses on the development of a project based on a biogas plant, characterized by low-cost technologies, located in the Andean region of Apurimac, in Perù.
This action has been taken after analysing the real situation of the people living in that region that were facing two main issues: the safe production and management of heat and energy and the recycling of waste of the everyday life.
According to this it has been evaluated that most of the time, women and children were involved in the production of energy, through the collection and harvesting of wood and other raw materials useful for the production of heat.
To this extent, the intervention has been made in order to find a good and suitable solution to face both challenges, and results have been conducted and then summarized as complementary study to the technical approach.
The main reason why the gas solution has been realized is it has been recognized in this project as the best solution to improve the living conditions of rural communities settled in Apurimac area, also taking into account the disadvantages that they have to face in such a complex and extraordinary environment.
Therefore, such project is presented at all stages of development, including the main technical parameters used in the plant realization. This topic has been deepened during many months of fieldwork in Peru, and the described work covers both the on-field activities and the subsequent related insights [2].

Social and environmental analysis

All the activities took place in the abovementioned Apurimac region, in the central-southern area of Peru. This region is characterized by little villages dislocated on the Andean mountain range, this fact causes many supply especially concerning medical assistance and, energy, raw materials and communication access.
Apurimac's surface is about 20.892 $km^2$and the main city is Abancay. The region takes its name from the Apurimac River which outlines the east border with the Cusco region points out Apurimac is the most deprived regions of Peru: in particular, the provinces concerned by the current project, Antabamba, Andahulyas and Vilcabamba, are some of the most disadvantaged; also the rate of illiteracy is an issue to be considered[3].
The environmental safeguard is a crucial issue of this region and this theme is strictly related to waste collection and energy supply, points that we would like to address in this paper.

Waste collection is almost non-existent, so that, outside the inhabited centres, it is common practice to deposit wastes in makeshift open-air landfill.

There isn't any precise institution planning on this issue and no specific education and regulation is applied in the area.

This last aspect creates serious environmental damages considering for example hospital or chemicals wastes and flammable substances that are not correctly stocked and disposed. Regarding the energy needs, great part of the region has no access to electricity, an example is the Antabamba province where only 43% of the population can directly access it.; the same happens in Grau province with an electrification of 50.7% [4]. The quality of the electric service is then very deprived, the energy is only supplied in some hours of the day and at very high prices, thus representing an unsustainable cost for residents and small businesses in the area.

Starting from these considerations a survey has been conducted in order to match the big problem of energy shortage with the rural resources of the rural villages. Since mostly of the rural communities population of these areas lead lives centred on farming and agriculture activities, the developed idea was to exploit their natural resources and reinsert them in a virtuous circle of waste enhancement. From this analysis spins off the idea of installing a biogas plant, fed by livestock and biological wastes.

According to the TripleWins**Erreur ! Source du renvoi introuvable.**a sustainable development is linked to the correct management of some aspects linked to the progress of human wellbeing; it is about wealth creation that generates equality and opportunity; it is about consumption and production patterns that respect planetary boundaries and increasing tolerance and respect for human rights.

TripleWins development approach states how integrating social development with economic growth and environmental sustainability really brings to a sustainable development.

For this reason, this paper tries to approach the analysis of the project, counting on these three pillars of the sustainable development.

The technical approach

The choice of biogas digester has been made since it integrates perfectly in a family rural based economy; addressing in this sense the social development, while helping in management of the family economy, avoiding duties especially carried by for women and children; this is the reason the biogas is indeed produced through the fermentation of common organic substrates available in any temporary or permanent camp, such as organic refuses or human waste.

The biological and chemical process that stands behind the biogas production is called anaerobic digestion, that is the natural breakdown of organic material by micro-organisms in the absence of oxygen. The final results of this process are methane and carbon dioxide and in lower part oxygen, nitrogen and hydrogen sulphide.

Another secondary product of the anaerobic digestion is the digestate, the remaining material after the digestion process that can be used as a fertiliser.

The produced biogas is most often used as a cooking fuel, but can also be used to heat water or generate electricity for on-site use.

The concept of this small-scale biogas plant has been designed in order to not require invasive buildings and wide initial economical investment; the potential return, considering therefore the biogas plant as the main element of the recycle process in agricultural context, is very high.

Other advantages of this type of plant are the versatility, this technology allows to be set up easily and in a short time, and that the biogas production can start soon after the first organic matrix charge.

This entire process addresses both economic and environmental sustainability aspects, helping in recycling wastes and saving money for the community itself, saving time for collection of other fuel and at the same time educating people living in such a fragile area like the Andean Regions in caring about their health and, finally, about the landscape they can preserve.

The principal biogas plant features are related to the process that starts up the biogas production, the anaerobic digestion: the natural microbiological process whereby organic matter is decomposed in complete absence of oxygen. One of the results of this process is the biogas itself, a mixture of methane and carbon dioxide, usable as combustible gas. The biogas production closely depends from the quality of the reactor that guarantee the oxygen absence, this tank takes the name of bio digester.

Various groups of microorganisms are involved in the anaerobic degradation process which generates also another product, a nutritious digestate usable as fertilizer.

The biogas production has many environmental and economic benefits, the principals are the exploitation of a renewable energy, the greenhouse gases reduction, a reduced dependency on fossil fuels and closing of the nutrient cycle. This last point has an increased value and an evident social impact referring to rural context where it is possible to easy obtain organic matrix, such as from agriculture or farming, spreading independency conditions for dislocated and remote villages and families.

Therefore, the real advantage of the anaerobic digestion process is to transform organic waste material into valuable resources while at the same time reducing solid waste volume. Biogas also contributes to the preservation of the natural resources by reducing deforestation, due to firewood employment, and to environmental protection by reducing the usage of fossil fuels; it solves also another health related problem caused by the combustion smokes inside close ambient that could conduct to ophthalmic and respiratory diseases.

Technology description

The selected biogas plant has been the so called tubular digester (fig. 1), an insulated tank composed by a tubular plastic bag closed on both sides. This volume is laterally distended on the ground and the organic manner lays in its lower part; the inlet and outlet ducts are attached directly to the skin of the balloon at the two lateral sides. As a result of the longitudinal shape, the digested flow is conducted through the reactor in a plug-flow manner.
The organic matrix, inside this oxygen-free ambient, starts to be subjected to the anaerobic digestion process and, after a precise number of days principally defined by the internal temperature, to the biogas production. The biogas produced is collected in the upper part of the digester, increasing its pressure together with the biogas volume. At the desired pressure, in the order of few bar, the biogas is acquired and, after some different treatment in order to purify its chemical composition, it is stored ready to be used.

Fig. 1 - Low cost tubular biogas plant

These type of digesters need to be placed partially underground to ensure as much as possible the constant temperature and also to protect themselves from mechanical damage. Another expedient to preserve the tubular tank is the creation of a structure around it that could also maintain more stable the inside temperature. For this reason, one of the benefit of these digesters is that they can be constructed at low cost by standardised prefabrication with no special planning activity.

Resuming the principal advantages and disadvantages of this technology a table is presented here below:

LOW COST TUBULAR BIOGAS PLANT	
ADVANTAGES	**DISADVANTAGES**
• Low cost construction	• Relative short lifespan
• Easy to construct and transport	• Susceptibility to mechanical damage
• High digester temperatures in warm climates	• Material usually not available locally
• Easy emptying and maintenance	• Low gas pressure requires extra weights
• High impact on health and hygienic conditions	• Scum cannot be removed from digester
• High impact on waste recycling	• Local craftsmen are rarely ableto repair a damaged balloon
• Shallow installation depth suitable for usein areas with a high groundwater table orhard bedrock	

Plant description

In order to get the best results for the community involved in the project, the general study of the technical settings is essential; in the following paragraph it will be analysed the optimal way and the economical outcomes of this installation.

The first crucial aspect to take into account is the positioning of the biodigester. The location of the reactor must consider the optimal orientation respect the solar orbit in order to collect as much solar radiation as possible. Defined this, the next step consists in the excavation of the protection trench for the tube digester, its dimensions depend strictly on the plant size. The four lateral trench walls are often projected to be inclined in order to avoid their crumble and to wrap the digester profile. It is important to define some geometrical criteria to optimize the structural strength of the construction, these information are available on literature as it is shown in fig. 2 [6].

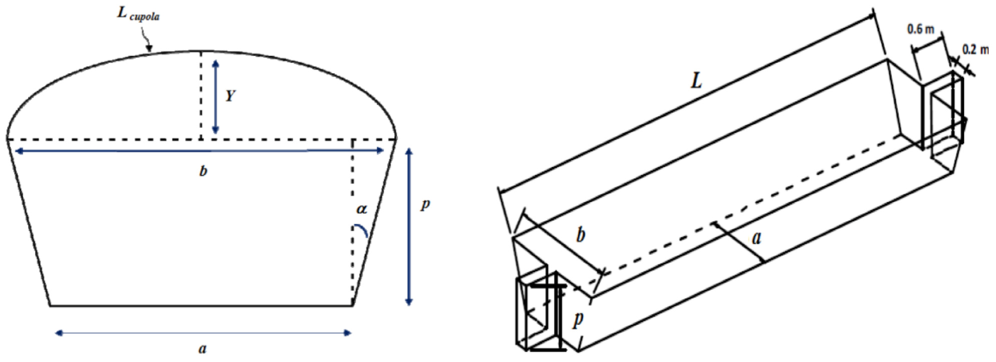

Fig. 2- Tubular section and trench geometries

The trench will protect the polyethylene structure for half high, the second part will be protected by a superficial wall, generally realized following the local building tradition. In the Andean context, like in most of the Latin America, this wall is built using the *adobe* technique, a mixture of soil, water and straw that is shaped thank to mold usage. The two lateral walls, placed on the two largest dimension of the tubular, are structured to permit the positioning of an inclined plastic surface on them in order to set up a greenhouse configuration. Obviously the optimal orientation is from East to West, and the optimal inclination of the plastic surface depends on the considered latitude, in the analysed case it is around 20°.

All the internal walls have to be covered by a thermal insulant, like polystyrene, in order to isolate the biodigester from the ground humidity, to limit the heat dissipation and also protect it.

The biodigester structure is realized using a tubular polyethylene roll, closed at the two lateral extremity with one PVC drainpipe of about 6’’ for part. These two pipes are necessary for introduce the organic matrix inside the digester and to allow to the digestate material to flow outside. For the communicating vessel theory it is necessary to locate the inlet pipe in a higher position respect the outlet one.

On the top of the digester is also essential set up a third hole in order to spill the produced biogas flow.

The next construction phase is represented by the positioning of the digester inside the trench, it is important notice that this operation will be simpler with a slightly inflated digester. After that, it will be possible cover the structure with the plastic surface necessary to recreate the greenhouse effect around the biodigester [7].

The produced biogas will be connected to its final end-user device thanks to a pipeline that need some more elements all along its length, such as:

- *filter*: in order to limit the hydrogen sulphide content in the biogas, it is useful arrange a simple filter composed by a steel wool. The hydrogen sulphide could be very aggressive respect metal component of the system; to warranty a correct filtration process it is recommended to change the filter every 6 months.
- *gasometer*: it is an additional storage respect the gasholder of the tube digester, it is composed by a plastic bag of the desired volume. It is also very important for the managing of the biogas pressure before its utilization. These reservoirs are installed closely to the usage location, but must be always protected against flames, sun or wind. Generally, to increase the biogas pressure, some weights are located on the gasometer in order to compress the inside volume of gas for an increased combustible supply (fig.3 dx).
- *lock valve*: it is useful set up some lock valves all along the pipes in order to facilitate maintenance operations and other management actions.
- *condense drain*: it is important to fit a valve in order to drain out the condensed water inside the pipe lines. For this reason, it is fundamental put this drain-valve in the lower part of the plant so that the condensed water collection will be natural. In this manner, it is possible to open the valve and to let out the accumulated water. It is possible too, to make the supply line ever with an incline, so that the condensed water flows to the security valve.
- *pressure valve*: this valve allows to control the digester pressure exploiting the water column pressure contained inside a receptacle, like a simple plastic bottle. The biogas line is split in two lines with a t-fitting, one of these two arrive in the pressure valve. As higher is the water column as higher is the working digestor pressure, if this limit is exceeding, the biogas come out until the inside pressure became comparable to the water column one.

At the end of the pipelines composed by the described elements, it is arranged an end-user device to exploit the biogas combustion to produce heat or light. So, the main applications of this technology are domestic stoves (fig.3sx) and gas lamps. The focus of the present work has been on stove application, considering it higher impact on the examined community. Actually, as stated above, this type of application prevents many respiratory and ophthalmic diseases caused by indoor combustion for food preparation[8] [9, Pérez, Garfí, Cadena, Ferrer].

One of the principle characteristic of the described plant is its cost-effectiveness, the economic assessment of the tubular digester is principally related to the to the PVC membrane component, for example, a membrane realized for this type of application, has a cost of about 40 $/m^3$. As previously described, it is also possible reduce this price, referring to the many publications and creating the digester starting from an open tubular PVC membrane and then adapt it in order to make it airproof. The other elements, such as bricks and cement are accounted for 30% of the total cost, manpower is about 7% of total cost.

A critical aspect of this type of plant is the plastic component lifespan, that is around 5 – 7 years. While for other components the lifespan is about 20 years, the digester and the greenhouse plastic require to be changed after the first degradation signs.

In order to fix some point on the productivity of this technology an example is presented. A tubular digester of 10 m^3 can produce 1,2 m^3 per day, with 10 kg of volatile solid (the organic matrix fraction that actively contribute to biogas production) per day.

This amount of biogas can effectively contribute to the sustenance of a family, therefore, it can guarantee the utilization of a stove for 2 hours per day or the functioning of a lamp for 10 hours per day.

Fig. 3 - Stove fed by biogas and biogas gasometer

Considering all these aspects it is relevant underline that support the diffusion of this technology in specific geographical areas and in specific social and environmental contexts, could be a good argument to promote the development of rural communities, empowering the lives of inhabitants, especially of the weakest part of the population, usually involved in domestic issues and eventually consequent damages and accidents.

Conclusion

The paper aim is to investigate the impact of a specific technology on an Andean rural community. Such technology exploits the potential of the anaerobic digestion and consists of a low cost biogas plant. The effectiveness of this type of installation is mainly characterized by a simple maintenance and management, and by a very well integrated process inside the reference context. This technological inclusion in a specific geographical area is a good example of foreign aid project since it has considered the social aspects necessary for the proper long term community development.

The Triple Wins approach has been favourable in analysing the project, evaluating the positive social impact together with a better energy efficiency and an economic growth, making the people able to extract energy form wastes. The good results of this project came out while people of neighbourhood of the principal village involved, came to visit the plant in order to replicate it.

The indirect impact states in a practical spread of waste reuse and management, so possibly bringing to new policies (and maybe laws) regarding the waste collection and recycling.

Form the health point of view, using biogas helps in slowing down smoke produced by burning wood or wastes in an uncontrolled way, de facto helping reduction of bad smokes and bettering the air condition along with that the pulmonary diseases.

All in all the impact, although still not measurable in terms of economic growth, is positive on the entire community and a long term assessment will give more and more details on the impact and measurable aspects could be took in consideration in order to produce documents able to analyse and replicate this case history of success.

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