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Business Models for Sustainability of Biogas Technology

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Absttract: Biogas is such a solution which produces clean and renewable energy, reduces the need to import fossil fuels, create jobs for skilled and unskilled persons and provides a new stream of income to farmers and investors. For more sustainable development of this technology, policy-makers should reform the existing institutional framework by reorganizing subsidies, motivating and attracting investor with flexible financial conditions, liberalizing the management of gas grids and involving farmers in local projects. In most of the cases, biogas projects become unsuccessful due to the lacking of financial attractiveness. Therefore, it is a great challenge to find a proper mode of design and implementation of biogas installations that ensure participation, ownership and responsibility of the final users and a sustainable financing mechanism. Community business connectivity can have played an important role in stimulating and shaping the spread of biogas technology. This study proposed a number of business models and micro-economic evaluation systems to calculate their economic viability which could play role to improve the sustainability of the biogas technology.

Key words: Biogas technology, business models, economic viability, skilled, financial

INTRODUCTION

The global megatrends such as climate change, depletion of fossil fuel, green house gas effect and global warming are driving the increased adoption of renewable energy sources. The price volatility, supply issues and environmental hazards of fossil fuel production are about to accelerate the pace in the investments of non-fossil fuels production. Particularly, biogas bears the potential to bring a basic change in the energy supply of rural households in developing countries. Biogas technology offer environmental, health and socio-economic benefits for farmers, localities and even at a national level. Furthermore, it bears the potential to facilitate an independent economic development of the area when applied as communal business. Though, biogas technology is easy, accessible and applicable to both developed and developing countries compared to other biofuels like biodiesel, bioethanol and biohydrogen, its dissemination is still limited by economic factors. Even, top rated biogas producer countries (USA, Germany, Austria, Greece, China, India and Sweden) are also providing governmental and non-governmental subsidies (Bond and Templeton, 2011; Borjesson and Mattiasson, 2008; Emmann *et al*., 2013; Tsagarakis and Papadogiannis, 2006).

In the least developed countries biogas technology is mainly using by small scale farmers when these farmers have enough livestock for running a small scale biogas plant (Buysman and Mol, 2013). Major constraints of the biogas technology are related to lacking financial attractiveness, although highly subsidized and to the conditions to be met by households: they require a minimum amount of cattle, access to water and a financial contribution to construction cost. Unfortunately, the majority of households is excluded from these programs by default due to their inability to meet the conditions. However, biogas bears the potential to bring a basic change in the energy supply of rural households in developing countries.

Presently most of the biogas plants are either heavily subsidised or entirely paid by donors. After 1 or 2 year majority of these plants become out of operation because of a lack of technical support of user training on maintenance and operation and of a viable financial model. In most of the cases the technology is seems

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relatively expensive to small farmers or rural people, even they do not have preliminary knowledge to use and maintain the digester. Often use of biogas equipment does not fit in existing cooking and fertilizing practices of the farmers, no institutional arrangements are made to maintain and repair the broken down installations and the programme stops after donor aid ends (Bond and Templeton, 2011; Parawira, 2009). Therefore, numerous small-scale projects report temporary successes but major failures on the longer term and at larger scales.

This study therefore proposes some innovative ideas, strategies and models to sustain the community/institutional and large biogas plants involving social benefits. The study alsodiscuss how to face the challenge to find a proper mode of design and implementation of biogas installations that ensure participation, ownership and responsibility of the final users, how to confirm social, economic and environmental returns from biogas technology, all over the longer periods of time.

MATERIALS AND METHODS

Types of biogas plant: There are 3 types of biogas plant-individual household units, community/institutional plants, large-scale commercial operations are presently using around the world. Most of the study reported that family size biogas plant are inefficient regarding initial construction cost, labor cost, feedstock availability, operation and maintenance (Adeoti *et al*., 2000; Amigun and Von, 2010; Reddy, 2004). Only the rich farmers can therefore acquire individual biogas plants. Most of the rural households do not own sufficient cattle for adequate manure supply. Hence, cattle excrement dependent substrate for biogas production may not generally be feasible. Moreover, family-sized biogas plants are inapplicable in urban areas because dwellers live there in clustered in a building and multistoried apartment.

Adeoti *et al*. (2000) studied a micro-economic analysis for 6.0 m^3 family-sized biogas project in Nigeria and their results showed it was infeasible in finance. A family-sized biogas plant may not be economically feasible unless it is used for productive purposes like irrigation, motive power and other commercial purposes in addition to providing fuel for domestic cooking. The economics of large-scale biogas plants, probably to serve communities, could be investigated since they may have a much higher benefit-cost ratio compared to family-sized plants (Akinbami *et al*., 2001). A community plant for 56 households was estimated to cost only about 6 times as much as a family-size (Reddy, 2004). Large-scale biogas plants include community-sized and commercial plant. Community-sized biogas plant can be establish both in rural and urban areas whereas commercial plant could be set up behind the city, vegetable market, agro-industrial area, animal firm and garbage disposal area.

Investment in a biogas project: Investing in renewable energy generates long-term predictable revenues streams. There is no shortage of investors but renewable energy sectors are still new, so it seems to a risky investing zone and less understandable to private and public investors. Practically, they are an excellent low risk opportunity because most governments around the world are suffering shortage of electricity, therefore they offer generous subsidies, guarantees and tax breaks.

On the other hand, social and environmental benefits of biogas project is not ignorable compared to its fuel values whole world even global humankind will take the welfares of this business. Methane (CH_4) is a greenhouse gas over 20 times more effective in trapping heat in the atmosphere than carbon dioxide (CO_2). As a result, efforts to prevent methane emissions can provide significant environmental benefits. Capture and processing of methane can generate carbon offsets with a commercial value on a carbon market. Furthermore, every ton of methane from animal slurries converted to biogas saves the equivalent of 21 tons of CO_2.

The key drivers for existing biogas plants are, to supply cooking fuel in rural area, to reduce odors from abattoirs or rendering plants, to generate electricity for landfill sites and wastewater treatment plants, to reduce pressure on fossil oil and gas. However, investing in anaerobic digesters can also be justified to produce fertilizer to increase water efficiency or to derive revenues from renewable electricity production and to create new jobs and business.

The heat, steam or electricity produced from waste processing can be used on site to operate a business which can offset part or all the cost of buying energy from the electricity network. Any surplus energy can be commercialized asgreen energyand sold back to the grid. Facilities that want to generate part of their own power requirements and sell electricity surpluses will need to negotiate with electricity distribution network owners. However, to attract the investor in biogas technology, the government should offer some relaxations in this sector like:

- Providing non-arable land for free of cost or with minimum cost
- Bank loan with flexible conditions

- Low cost insurances to guarantee plant performance
- Tax free capital gains in an enterprise investment scheme for biogas plants
- Dividends also should be tax-free
- Support to build a biogas market and create linkages to farmers through promotion, marketing and networking through women associations, local authorities and NGOs/associations
- Media/advertising support to popularize the technology

In 2012, a research group, PIKE (Penn State Information, Knowledge and wEb) has published an attractive outcome of their research that may encourage the biogas investors. PIKE research is a market research and consulting firm that provides in-depth analysis of global clean technology markets. It suggests that the global commercial biogas market will more than double in the next ten years as their findings is presented in Fig. 1. According to Fig. 1, this fast-growing market reached $17.3 bln in global revenue in 2012 and will be nearly double by 2022, hitting $33.1 bln. PIKE report analyzes the prospective global market for biogas demand considering 4 key industrial segments: municipal solid waste, agriculture, industrial and sewage treatment. It also provides a comprehensive assessment of the demand drivers, business models, policy factors and technology issues associated with the rapidly developing market for biogas production and utilization.

Socio-environmental benefits of biogas business: Most of the biogas projects become miscarriage because of related to lacking financial attractiveness although they are highly subsidized and to the conditions to be met by households. Community biogas plant or urban biogas project are till unattractive to the investors because of improper plan and policy, unavailability of success business model and cash-profit maximizing tendency of stakeholders. Communal business policy can overcome these limitations where it is able to achieve the goal of profit and non-profit business organizations.

Figure 2 briefly presented the socio-environmental benefits of biogas technology. Since, the energy crisis and environmental instability is the global issue, the government should take it as non-profitable investment sector. Survival of this technology will give much more to the society rather than monetary profit like pollution free environment CO_2 reduction; continue energy supply, work for jobless people, extra income for farmer, etc., in many countries, organic wastes from various sources including livestock, industries,

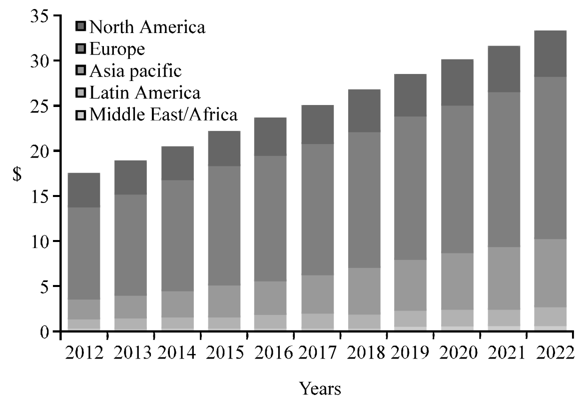

Fig. 1: Biogas world market value ($ in billion) by region: 2012-2022 (PIKE research) (http://www.navigantresearch.com/research/renewable-biogas)

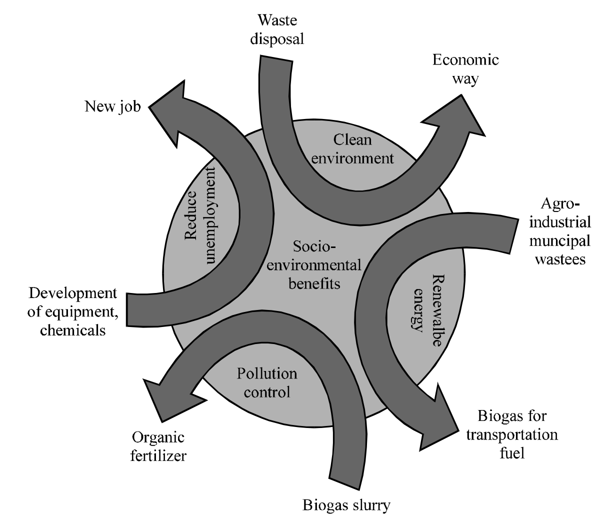

Fig. 2: Socio-environmental benefits from biogas technology

agriculture and households are consider as a great threat to the environment. Anaerobic digestion is an easily affordable established techniques to manage biodegradable wastes because they reduce waste volumes and yield biogas and residues rich in plant nutrients which can be used as fertilizers to return nutrients back to the soil ecosystem and as a pest control agent (Abubaker *et al*., 2012; Chen *et al*., 2010; Odlare *et al*., 2011; Svensson *et al*., 2004). Therefore, biogas is an integrated biotechnology that offers a number of social, economical and environmental benefits.

Biogas business models: Communal business of biogas technology will be effective and fruitful in those countries where unemployment is a great issue, especially in developing countries. Figure 3 proposes

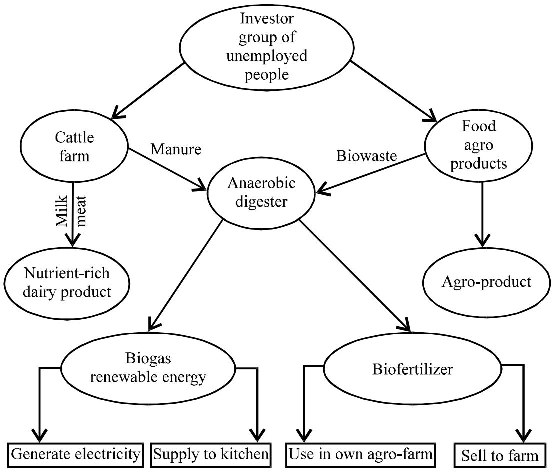

Fig. 3: Proposed communal business model for commercial agro-based biogas plant

some non-energy-product business such as meat, milk, nutrient rich dairy product, agro-food, biofertilizer. Most of countries in the world are facing the deficiency of milk and milk derivative food product as well as vegetable protein. Therefore, the demand is always high of these food items. If any business group follows the proposed communal business model, their risk will be strangely minimized.

The prime social benefit is offering by occupying unskilled people in the cattle farm, food industry, biogas distribution and biofertilizer processing. At the same time, this model will also create employment opportunity for skilled and professional person, e.g., in the stage of nutrition-rich dairy product and agro product. There are several ways to make monetary profit from this model, say by marketing, milk/meat, nutrition-rich dairy product, agro-product, biogas, electricity from biogas and organic fertilizer. In the United States (US) about 5% of the population lived in cities in 1800 but about 50% of the population lived in cities by 1920. Throughout the 19th century, the US was urbanizing. The same was true for most European societies during the 19th century. Today about 80% of the US population lives in cities and suburbs. The number of people living in cities surpassed those living in rural areas and it has been estimated that by 2050, 6 bln people will be living in cities compared with 3.5 bln. now (Tsagarakis and Papadogiannis, 2006). Demand for energy is driven by 2 main factors- population growth and economic development. Thus the use of energy is overwhelmingly concentrated in urban areas, where 75% of the energy consumption takes place and the urbanization trend remains firm.

There is possibility to produce higher amount of biogas from urban organic wastes using same volume of rural cattle farm wastes. It is reported that food waste yields 15 times more biogas per ton than farm waste (Curry and Pillay, 2012). This is instinctive because the manure has already been digested in animal stomach and therefore large amounts of the energy have already been removed. Considering this fact, we proposed communal business model for urban-based biogas plant as presented in Fig. 4. The produced biogas could be used for multipurpose-supply to refueling station in cylinder for cooking and generate electricity. Due to high demand of energy in the above sectors, the risk of the proposed business plan is tends to zero. However, before starting the investment, economic viability must be calculated. At the same time, priority should be given on the purpose to produce biogas for the urban city buses in order to reduce the local, regional and global emissions from the urban transport system as well as certainty of better living environment.

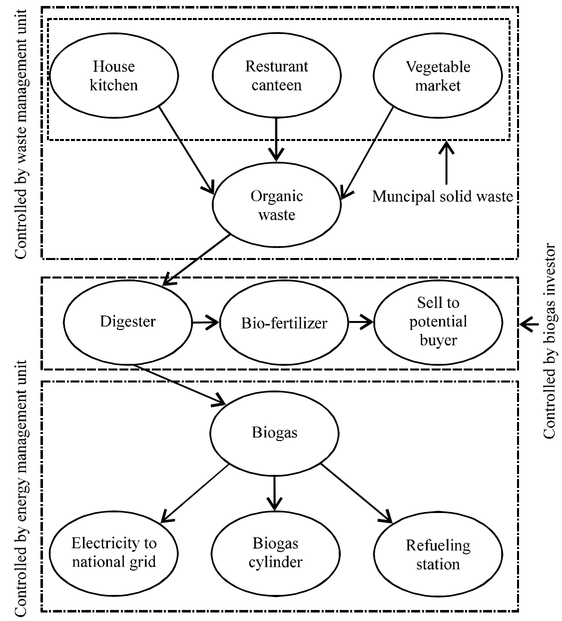

Fig. 4: Proposed business model for commercial urban-based biogas plant

There are some institutions where biomass is generated in huge amount in a short area like big restaurant, college university student dormitory, cafeteria, vegetable market, etc. Biogas plant in those areas may play a role to make them self-energy dependent. Small management unit can successfully run a biogas plant. Figure 5 shows some symbolic institutional sources of biodegradable waste. Management unit (operation cost) can be run from the profit of biofertilizer selling and excess biogas selling. Of course, institutions can also save their cost from the self-using of biogas instead of cylinder gas or grid gas. A successful institutional biogas plant has been established in Osaka Prefecture University (OPU) in

Table 1: Institutional biogas business scope and its effects on CO_2 emissions reduction

Variables	Motorcycle	Buggy	Vehicle (within the premises)	Vehicle (outside the premises)
Biogas storage capacity (m3)	1	3.5	0.5	12.5
Mileage (km)	50	80	7	175
Mileage per day (km)	5	10	7	50
Annual number of operation days (days)	200	200	200	200
Required monthly number of cafeteria users (people)	506	2212	2528	18057
Annual disposal amount of glycerin (L)	9.74	42.6	48.7	348
Annualreduction of CO_2 emissions (kg)				
BDF	170	744	850	6075
Biogas	44.1	193	221	1577
Total	214	937	1071	7651

Use; Delivery of mail, etc.; Travel within the premises; Material transportation within the premises; Material transportation from/to the premises

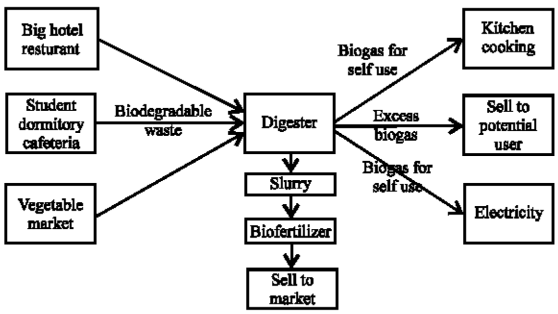

Fig. 5: Proposed business model for institutional-based biogas plant

Sakai, Japan, to promote a "Campus Zero Emissions" project, intended to recycle the resources within the campus. The other purpose was to launch a business model for OPU's resource recycling process using waste cooking oil and food wastes. They have a bench scale methane fermentation plant and Bio Diesel Fuel (BDF) production plant which is capable of producing BDF from waste cooking oil and methane from food wastes (Nishio and Nakashimada, 2007; Yang *et al*., 2008).

Tokumoto also proposed a business model based on the number of users of the 'co-op cafeteria' where large amount of waste cooking oil is generated. On an average 23,000 people per month take their meal in the 'co-op cafeteria' of OPU and 3,000 L of waste cooking oil are discharged annually. They calculated all the parameters of Table 1 considering the amount of glycerin derived from BDF production to be 1/4th of the amount of waste cooking oil. Table 1 sum ups the uses and utilizations of the biogas along with their effects on CO_2 emissions reduction which is a vital environmental benefit in terms of global warming and clean environment. By this research, they suggested that the business model could be applied to any business place that has a dining facility of hundreds people a month.

RESULTS AND DISCUSSION

Economic evaluation of biogas project/business

Lifetime of the investment: Future operating costs for project are often more difficult to estimate than the initial project investment cost. However, there are number of methodologies have been developed to minimize initial investment at the expense of future operating cost. One of the most popular economic methodologies is 'Design-to-cost' which is mainly used in defense industry. A project is evaluated using this methodologies basis on initial cost criteria without considering the implications of future operating costs over the life of the project. Another economic methodology Called Life Cycle Costing (LCC) attempts to overcome these difficulties. This method incorporates the sum of the initial investment cost plus the total operating costs over the life of the project.

LCC could be calculated for a biogas project from which electricity would be produced following Eq. 1 modified from Lakhani *et al*. (2014). In Eq. 1 all costs are discounted to reflect the present day value:

$$\text{LCC}\left(\frac{\$}{\text{KWh}}\right)=\frac{\begin{array}{c}\text{Cost}_{\text{plant installation}}+\text{Cost}_{\text{maintenance}}+\\ \text{Cost}_{\text{land}}+\text{Cost}_{\text{distribution}}\end{array}}{\begin{array}{c}\text{Total energy delivered}\\ \text{(during total system life)}\end{array}}$$

Tsagarakis and Papadogiannis (2006) studied biogas utilization for electricity production at Iraklio Municipality, Greece. They calculated the LCC of electricity production by the biogas plant considering the lifetime of 8-20 year. The cost per KWh for different quantities of KWh produced per year is shown in Fig. 6. It suggested that with the longer lifetime of the biogas project, production cost of per Kwh electricity will be reduced and after 20 year production cost may be bellow the purchasing price (national grid price) whatever amount of electricity would be produced per year.

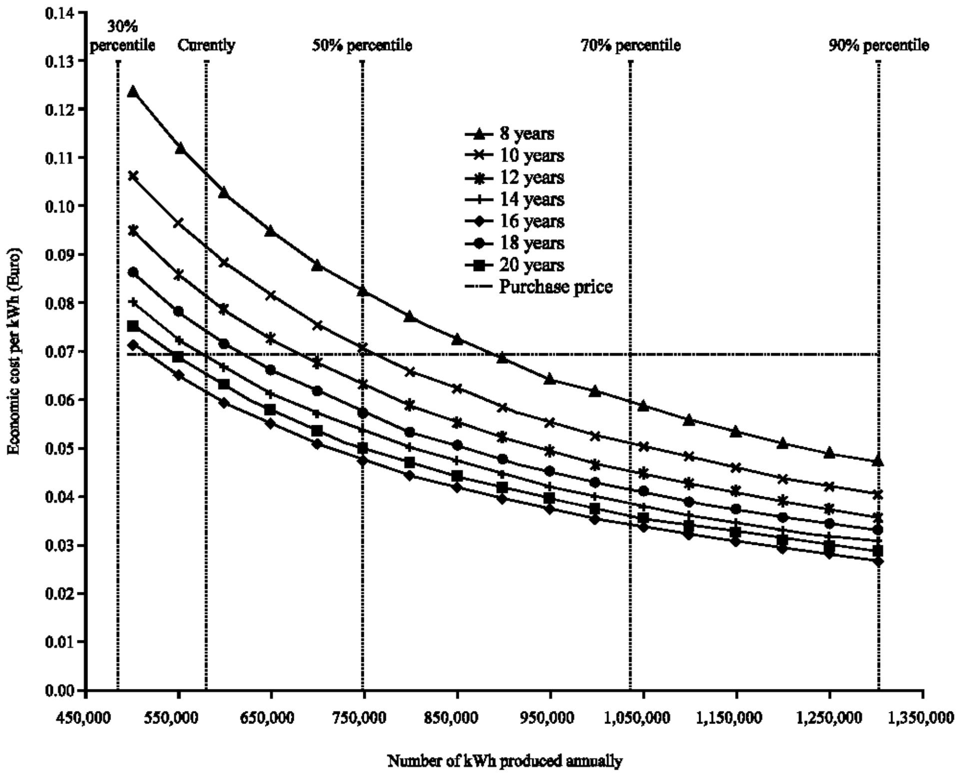

Fig. 6: Cost per kilo Watt hour for different quantities of kiloWatt hour per year produced (Tsagarakis and Papadogiannis, 2006)

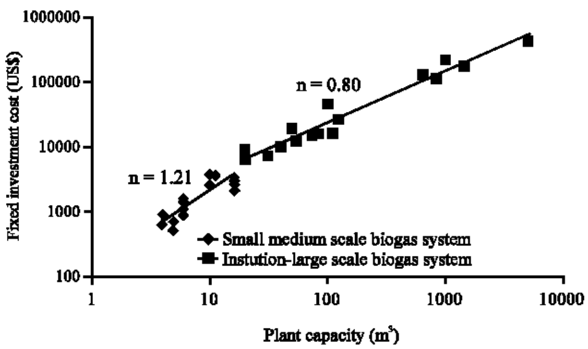

Fig. 7: Relationship of fixed capital investment cost with biogas plant size (small and large scale) (Amigun and Von, 2010)

Profitability evaluation: The financial feasibility of a biogas project can be asses following micro-economic analysis considering the benefit and cost of the project and inspect their ability to make profit from the perspective of the investors. Net Present Value (NPV) is used in capital budgeting to analyze the profitability of an investment or project. This is defined as the difference between the present value of cash inflows and the present value of cash out flows. NPV compares the value of a dollar today to the value of that same dollar in the future, taking inflation and returns into account. If the NPV of a prospective project is positive, it should be accepted. The calculating equation of NPV is Eq. 2:

$$\text{NPV} = -C_0 + \sum\nolimits_{t=1}^{T} \left(\frac{(C_b - C_c)_t}{(1+r)^t} \right)$$

Where:

$-C_0$ = Initial investment at t = 0
C_b = Cash benefit from the project
C_c = Cash cost to run/maintain the project
$(C_b\text{-}C_c)_t$ = Net cash flow for the year 't'
T = Project lifetime/calculation period
r = Discount rate

Investment projects are often evaluated using the Internal Rate of Return (IRR); it is the interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal to zero. Therefore, the equation forIRR is:

$$-C_0 + \sum_{t=1}^{T} \left(\frac{(C_b - C_c)_t}{(1+\text{IRR})^t} \right) = 0$$

If the IRR of a new project exceeds investor's required rate of return that project is desirable. If IRR falls below the required rate of return, the project should be rejected (Percoco and Borgonovo, 2012). This parameter is very important for the investor since it provides a meaningful estimation of the return of their investment. Unfortunately, equation must not be solved through analytical methods (Talavera *et al*., 2007). Instead, IRR must be found by using mathematical trial-and-error to derive the appropriate rate. Micro-economic analysis of a 6.0 m^3 family-sized biogas project in Nigeria became infeasible in finance where IRR finance <5.2%, the cut-off discount rate (Adeoti *et al*., 2000).

To assess a new project's profitability payback period is another important determinant of whether to undertake the project as longer payback periods are typically not desirable for investment positions. It is defined as the length of time required to recover the cost of an investment:

$$\text{Payback period} = \frac{\text{Amount to be initially invested}}{\text{Estimated Annual Net Cash Inflow}}$$

Singh and Sooch (2004) calculated payback period of three family size biogas plant with capacity from 1-6 m^3 and found that with increase in capacity the payback period decreased exponentially. The result conform the standard trends of the economics of installation and operation of any technical project.

Another study studied (Amigun and Von, 2010) the capital cost relationship for small and large scale biogas systems and showed that the cost capacity factor (n) decreases with the increase of the plant capacity (Fig. 7). According to the findings of their study for the plant capacity of 2-16 m^3 (family size) the cost capacity factor was 1.21 and this value was 0.80 for the plant size of >20 m^3. This is an indication of decrease in marginal cost of investment when the plant capacity (output) is increased. Therefore, community plants may be more economically viable than the smaller units.

CONCLUSION

Development and utilization of this enviable modern, ecology-oriented form of appropriate technology remain unpopular in most of the country mainly because of lack of information on its economic viability. To promote socio-economic territorial integration of biogas technology, execution of communal business can overcome the major barriers of economic unsustainability. The suggested business plans would be able to make an alignment between the technical, economic, regulatory and environmental context to provide the basis for building up a momentum, until the technology is able to survive on its own. There should be proliferation of applications to improve its economic feasibility-biogas use (in vehicles, cylinder) as alternative of compressed natural gas may be one of the extended applications. The authority has to be committed to decentralized energy systems based on utilization of local resources. Finally, implementation of communal business and unemployed microcredit could play a major role in this challenge.

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