Assessment of Waste to Energy Potential in the Central Zone of Afghanistan

Abdul Ghani Noori, Agha Mohammad Fazli

Abstract—The central zone of Afghanistan has enough cattle to be considered for generating biogas. The cattle population in the zone was 634,524, 647,229 and 633,362 heads in 2012-13, 2014-15 and 2016-17, respectively. As a result of field experiments, the fresh manure generation of cattle in the zone is 19 kg head⁻¹ day⁻¹, fraction recoverable of the generated cattle manure is 80% and the proportion of dry matter of the manure is 23.7%. Based on these manure parameters, about 834,320, 851,026 and 832,792 tons of dry matter recoverable could be generated in the mentioned three years, respectively. By using a biogas digester, this dry matter recoverable could be enough for generating about 86,769,319, 88,506,691 and 86,610,419 m³ of biogas in 2012-13, 2014-15 and 2016-17, respectively. The amount of generated biogas is equivalent of 1,735,1,770 and 1,732 TJ of energy in the mentioned years, respectively. In the case study of Kabul province, it was found that till now biogas plants are not constructed in the zone. For financial evaluation of biogas utilization, a dairy of 24 cattle was selected. It was determined that the manure from 24 cattle can generate about 9 m³ per day (3,285 m³ per year) of biogas in a 24 m³ DSAC-Model biogas digester. By comparing biogas energy value from the equivalent energy of LPG, biogas has value of 66,521.25 Afg per year (978 USD per year). By considering the requirements of cooking and lighting of a family of 8 members, the generated biogas (9 m³/day) in the mentioned dairy farm can be enough for two families. Considering the situation of the zone DSAC-Model biogas plant was considered suitable among various types of it. The techno-financial analyze result was quite attractive. For this case, the NPV was 2,664.6 USD, B/C 2.37, IRR was 33% and the discounted payback period (PP) was 4.09 years (4 years and about one month). As all these financial indicators are in the acceptable range, therefore the biogas generation with DSAC-Model biogas plant in the central zone of Afghanistan is beneficent.

Index Terms—Cattle Manure, Biogas Energy, Central Zone, Afghanistan.

I. INTRODUCTION

Biomass energy plays a vital role in the total energy supply chain of Afghanistan. The country has a lot of biomass energy resources like animal manure, fuelwood, charcoal, crop residues, and etc. As of now the utilization of these resources is very inefficient. Mostly, open burning and inefficient cook stoves are used in the households. As a result, the degradation of resources and health problems are occurred. The energy potential of these biomass resources is unknown and their efficient usage is not suggested in the country. Animal manure is the main energy source along with crop residues and wood in the country. In Afghanistan, the women and children make the manure cake and then the sun dried manure cakes are used for cooking and space heating. They burn this animal manure directly, which is not the efficient way for using it. As an alternative, this manure can be used for biogas production, which provides better and clean fuel than the animal dung. Burning this manure in the open fire stove causes indoors air pollutants and other respiratory diseases, but biogas is a cleaner, odorless and smokeless fuel. In addition to it, biogas can be also used for lighting and refrigeration. Cattles are the very dominant animals, kept by most of the families in all over the country. Generating biogas from cattle manure has two very dominant advantages; first, biogas is a cleaner fuel than cattle manure; second, the digested cattle manure which is called slurry is a very harmless fertilizer for the agriculture. However, the utilization of biogas is very common in our surrounding countries such as, India, China, Nepal and Pakistan [1]; the people of Afghanistan are unfamiliar with this source of renewable energy. To take the advantage of this renewable energy source in Afghanistan, it is required to find its potential and techno-economically analysis it for a zone. For this purpose, a study on the biogas energy potential of cattle manure and techno-economic analysis of biogas utilization in the central zone (Kabul, Parwan, Kapisa, Logar and Wardak) of Afghanistan were conducted.

II. LITERATURE REVIEW

A. Livestock in Afghanistan

Afghanistan is an agricultural country. In the agriculture GDP, 50% share goes to the livestock products. The livestock population has fluctuated over the past 30 years, from about 4 million cattle and over 30 million sheep and goats to 3.7 million cattle and around 16 million sheep and goats in drought years [2]. In Afghan agriculture sector, animals play an important role. Nearly, 79% of rural households and 94% of nomads (Kochyan) population keep some kind of animal like cattle, oxen, horses, donkeys, camels, goats, sheep, and poultry not only for meat, dairy products, eggs, but also for providing the cooking fuel and fertilizer [3]. Nowadays, in the agriculture sector of the country, there are a lot of small scale dairies in the urban and suburban areas, which is a good way of revenues to the farmers. The cattle manures produced in the dairies are used for domestic cooking and as fertilizer for the crops in the rural households. The main livestock kept by afghan people are cattle, sheep, goats, donkeys and camels [1].

The manures of cattle are a very potential source for...
generating biogas. Biogas generation is very common in the world. Globally about 30 million households use biogas for cooking, heating, and lighting [4]. Most of these populations are in China (25 million biogas digesters), India (nearly 4 million biogas digesters), Nepal (200,000 biogas digesters), and Vietnam (150,000 biogas digesters). In contrast 75 biogas digesters was in operation in Afghanistan in 2010 [5]. Based on the number of animal from statistics of 2008-9, the theoretical biogas potential in Afghanistan was about 1,408 million cubic meters (32 trillion Btu) per year, which is double of the energy consumption in 2005 (18 trillion Btu) [6]. By using cattle manure, nearly 896,000 domestic biogas plants could be installed in Afghanistan and about 26% of the households could be revived by the efficient and clean fuel in 2008-9.

B. Biogas Technology

Biogas is produced by the microorganisms through the anaerobic fermentation of biodegradable biomass. In this process, the organic fraction of biomass is digested by bacteria in an anaerobic environment. As a result, CH₄, CO₂, H₂ and the decomposed mass are produced. Depend on the feeding materials and its degradable fraction, biogas has different composition, about 50% to 70% is methane (CH₄), 30% to 40% carbon dioxide (CO₂), 5% to 10% hydrogen (H₂), 1% to 2% nitrogen (N₂), 0.3% water vapor (H₂O) and hydrogen sulfide (H₂S) in traces. Methane is a combustible gas. Its net calorific value is 20 MJ per m³ and the air to fuel ratio, required for its combustion is 5.7. About, 700°C temperature is required for its ignition and the density of methane is 0.94 kg per m³ [7].

C. Fixed Dome Biogas Plant

Fixed dome biogas plant is a single unit, where the dome acts as a gas holder and there is no moving part. This plant is constructed underground, which helps to avoid the effects of the temperature variations and let the upper space to be used for other activates [7]. The common types of fixed dome biogas plants are Janatha, Deenbandhu and DSAC-Model. Janatha biogas plant is an Indian design, which is masonry structure at all. The inlet and outlet tanks of the plant have a tank shape, from which the animal manure is fed and the digested slurry is extracted, respectively. The gas produced in the result of slurry digestion in the digester, goes up and collected in the dome. When the produced gas increases, it pushes the digested slurry to the outlet and also helps to pressurize the gas going out through the gas outlet. As this is fixed structure, the gas pressure is not constant like in the floating type [7]. Deenbandhu biogas plant is the improved version of the Janatha biogas plant, shown in Fig.1. It was developed in India by Action for Food Production (AFPRO) in 1984. This plant can be constructed with locally available materials. The construction cost of this model is cheap (30 - 45 percent then Janatha). The losses through the inlet chamber are less and its practical retention time (RT) is close to the theoretical retention time (RT). The structure of this model is composed of two spheres, having different diameters, joint at their bases. There is no need for the masonry walls around the digesters. The inlet and outlet of this plant is the similar to the Janatha biogas plant. To avoid the entrance of slurry to the gas outlet, it is constructed 150 mm below the slurry outlet. The gas holding capacity of this model is 33 percent of the total capacity of the digester [7]. DSAC-Model biogas plant is a rectangular fixed dome digester, shown in Fig.2. It was modified from the Chines and Indian models and used in the Philippines. The structure of this plant is totally from concrete, bricks and other similar locally available materials, so its structure is more durable. The plant is adaptable for small, medium and large scale applications with low cost investment. It is environmental-friendly and can reduce the pollution from 60% to 80%. In addition to that, it is self-stirring and can produce 35% to 60% biogas of the digester volume. [8].

D. Floating Drum Biogas Plant

The floating drum biogas plant is constructed underground from bricks and a metal circular dome, shown in Fig.3. A partition wall is constructed in the middle of the digester to avoid the mixing of fresh and digested slurry. The gas produced is collected in the metal structure. This metal structure is moveable. When the volume of the produced gas is increased, it goes up and the gas is withdrawal through the gas out let and then drops down. This drum is rotated horizontally to break the scum formation in the digester. For the vertical moment of the drum, a central guide frame is used. The cost of the drum is counted around 60 percent of the overall plant costs. The weight of the drum helps to provide the gas with a constant pressure. The inlet and outlet tanks of the plant are the same as in the fixed dome biogas plant. The gas pipe is provided in the top of the plant. This type is widely used in India [7].

Fig. 1. Fixed dome (Deenbandhu) biogas plant technical drawing [9]

Fig. 2. DSAC-Model biogas plant technical drawing [9]
III. METHODOLOGY

A. Determining Biogas Energy Potential

The animal manure is composed of organic material, moisture and ash. In the anaerobic environment, it is decomposed and produces CH$_4$, CO$_2$ and stabilized organic materials (SOM). The energy potential of animal manure through biogas production is estimated by the following equations [11].

$$\text{EP}_{\text{manure}} = \text{ABP}_{\text{manure}} \times \text{LHV}_{\text{biogas}}$$  

Where,

$$\text{ABP}_{\text{manure}} = \Sigma (\text{DMR} \times \text{VS} \times \text{Y}_{\text{biogas}})$$

$$\text{DMR} = \text{DM} \times \text{NA} \times \text{FR} \times 365$$

In the above equations,

- $\text{EP}_{\text{manure}}$: Annual energy potential of animal manure (TJ/y)
- $\text{ABP}_{\text{manure}}$: Annual amount of biogas from recoverable manure (NM$^3$/y)
- $\text{LHV}_{\text{biogas}}$: Lower heating value of animal manure (TJ/M$^3$)
- $\text{DMR}$: Annual amount of dry mater recoverable (kg/y)
- $\text{VS}$: Fraction of volatile solids in the dry mater (kg VS/kg DM)
- $\text{Y}_{\text{biogas}}$: Biogas yield (NM$^3$/kg VS)
- $\text{DM}$: Amount of dry mater (kg per head per day)
- $\text{NA}$: Number of animals
- $\text{FR}$: Fraction of animal manure recoverable

B. Method for Sizing DSAC-Model Biogas Plant

There are two approaches to size the biogas digester, determining the size of digester for a specific amount of slurry to be treated or determining the size of digester for a specific amount of biogas needed. If the slurry to be digested is known the following equations can be used to size the DSAC-Model biogas plant [8].

Slurry volume ($\text{m}^3$/day) = Animal manure ($\text{m}^3$/day) $\times$ 2 (manure to water ratio = 1:1)  

Digester volume ($\text{m}^3$) = Slurry volume ($\text{m}^3$/day) $\times$ RT (days)  

$$\text{Biogas storage dome rise from the top of digester, } f \text{ (m)} = 1/3 \times W$$

$$R \text{ (m)} = (W^2 + 4f^2) / 8f$$

$$\theta \text{ (degree)} = 2 \times \tan^{-1}[(W / 2) / (R - f)]$$

$$V_{\text{biogas}} = L \times (R^2 / 2) \left(\frac{\pi}{180} \times \theta - \sin \theta\right)$$

$$V_{\text{in}} = \text{Slurry volume (m}^3\text{/day})$$

Height of inlet pipe and manhole in the digester (m) = 1 / 2 x (H)  

Width of manhole (m) = 0.4 x W

Outlet tank volume ($\text{m}^3$) = 1/3x [Digester volume ($\text{m}^3$)]

C. Method for Financial Analysis

The financial analysis determines the suitability of investment. Usually, it is used to evaluate whether a project is stable and profitable enough to be invested in or not. These indicators are net present value (NPV), benefit to cost ratio (B/C), internal rate of return (IRR) and payback period (PP) [12].

- Net present value (NPV): is the summation of discounted net cash flow of the project.

$$\text{NPV} = \sum_{n=0}^{N} A_n \times (1 + i)^{-n}$$

Where,

- $N/h$: period of time (years)
- $A_n$: annual income
- $i$: interest rate

NPV excel command =NPV (i%, series of inflow) + out flow

If NPV > 0 (Accept the investment)
NPV = 0 (Remain indifferent)
NPV < 0 (Reject the investment)

- Benefit to cost ratio (B/C): is the ratio of the net benefit and expenses over the life time of the project. It is calculated in present or it the beginning of the investment period.

\[ B = \sum_{n=0}^{N} b_n (1 + i)^{-n} \]  

Where,
N/n = period of time (years)
b_n = annual benefits
i = interest rate

\[ C = \sum_{n=0}^{N} c_n (1 + i)^{-n} \]  

Where,
N/n = period of cost (years)
c_n = annual cost
i = interest rate

If,
B/C > 1 (Accept the investment)
B/C = 1 (Remain indifferent)
B/C < 1 (Reject the investment)

- Internal rate of return (IRR): is the discount rate which is used in capital budgeting, it equals the net present value of the project cash flow to zero. The higher the IRR, the more attractive will be the investment. IRR is calculated from the net cash flow of the project by excel as in the below equation.

\[ \text{IRR excel command = IRR (rang, guess)} \]  

IRR > MARR (Accept the investment)
IRR = MARR (Remain indifferent)
IRR < MARR (Reject the investment)

Minimum acceptable rate of return (MARR) is the interest rate by which the money is borrowed for investment.

- Payback period (PP): The required period of time to recover the cost of an investment. The shorter the PP, the beneficial will be the investment.

\[ \text{PP (years) = } \frac{\text{Initial investment}}{\text{Uniform annual benefits}} \]  

IV. BIOGAS ENERGY POTENTIAL IN THE CENTRAL ZONE OF AFGHANISTAN

A. Cattle Population

In the central zone of Afghanistan, groups of cattle are kept in dairy forms as well as in the households for producing milk. Keeping a group of cattle makes it easy to collect their daily manure for biogas generation. In this zone of the country, most cattle are kept in the Kapisa province followed by Parwan, Kabul, Logar and Wardak. In 2012-13, 2014-15 and 2016-17 the total cattle population in the central zone of Afghanistan was 634,524, 647,229 and 633,362 head of cattle, respectively. In Table I, it is shown that there is an increase of cattle population from 2012-13 to 2014-15 and back a decrease from 2014-15 to 2016-17 [13].

<table>
<thead>
<tr>
<th>Years</th>
<th>Kabul</th>
<th>Parwan</th>
<th>Kapisa</th>
<th>Logar</th>
<th>Wardak</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-13</td>
<td>99,636</td>
<td>173,052</td>
<td>199,272</td>
<td>83,904</td>
<td>78,660</td>
</tr>
<tr>
<td>2014-15</td>
<td>101,631</td>
<td>176,517</td>
<td>203,262</td>
<td>85,584</td>
<td>80,235</td>
</tr>
<tr>
<td>2016-17</td>
<td>99,454</td>
<td>172,735</td>
<td>198,907</td>
<td>83,750</td>
<td>78,516</td>
</tr>
</tbody>
</table>

B. Cattle Manure Parameters

For estimating biogas potential of cattle manure and energy potential of biogas, it is needed to find different characteristics of cattle manure, such as fresh manure generation per head per day, recoverable fraction of the fresh manure, fraction of dry matter, fraction of volatile solids, biogas yield and the calorific value of biogas. For determining these parameters, a dairy was selected in Kabul province of Afghanistan during data collection in December 2018. There were 24 cattle in the dairy. The cattle manure was collected twice daily, the fresh manure of these cattle was measured and its sample was taken for determining the cattle manure parameters. The field measurements showed that, the average per head per day fresh cattle manure production is 19 kg, and its recoverable fraction is 80 percent of total produced cattle manure. The recoverable fraction is so high compare to other countries, because Afghanistan does not have grazing areas for cow feeding, so they are always farmed in selected small areas. On the other hand, cattle manure has energy and fertilizer value in Afghanistan and cows standing areas are brick covered in most places, which help to collect the maximum amount of cattle manure. In comparison, the collection efficiency of cattle manure is 50 percent in Sri Lanka [14]; 60 percent in India [15] and 80 percent in Thailand [16]. The proportion of dry matter resulted from the field test is 23.7%. The other parameters are taken from previous study on biomass energy potential in other countries, such as cattle manure volatile solids percentage 52 percent [1], biogas yield 0.2 m³ per kg of volatile solids, and calorific value of 20 MJ per m³ of biogas, shown in Table II [14].

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh manure generation (kg head⁻¹ day⁻¹)</td>
<td>19</td>
</tr>
<tr>
<td>Fraction recoverable</td>
<td>0.8</td>
</tr>
<tr>
<td>Proportion of dry matter (%)</td>
<td>23.7</td>
</tr>
<tr>
<td>Fraction of volatile solid (kg VS kg⁻¹ DM)</td>
<td>0.52</td>
</tr>
<tr>
<td>Biogas yield (m³ kg⁻¹ VS) *</td>
<td>0.2</td>
</tr>
<tr>
<td>Calorific value of biogas (MJ m³)</td>
<td>20</td>
</tr>
</tbody>
</table>

C. Annual Dry Matter Recoverable from the Manure

The dry matter recoverable was estimated based on the cattle manure parameters described in Table II. The total dry matter recoverable in the central zone of Afghanistan in
2012-13, 2014-15 and 2016-17 was 834,320, 851,026 and 832,792 tons respectively. As most of the cattle population is concentrated in the Kapisa province followed by Parwan and hence the dry matter recoverable is also high in these two provinces compared to Kabul, logar and Wardak provinces. In Table III, it is shown that the dry matter recoverable has been increased by 2% from 2012-13 to 2014-15. And is back decreased by about 2.14% from 2014-15 to 2016-17. The estimated dry matter recoverable is used as fertilizer for the crops and fuel for cooking and space heating. There is no any study and data for Afghanistan to show the fraction of cattle manure used as fertilizer and for energy. The cattle manure cakes are sun dried, before using as fuel. Table III shows the annual dry mater recoverable from the cattle manure in the central zone of Afghanistan.

D. Annual Biogas Potential

By considering the cattle manure parameters and the dry matter recoverable, the biogas potential of cattle manure is estimated for the three selected years. As the biogas potential depends on the cattle population and cattle manure parameters; therefore, the most biogas productive provinces in the central zone of the country are the most cattle populated provinces Kapisa and Parwan. In 2012-13, 27,250,000 m³ and 23,664,000 m³ of biogas could be generated from the cattle manure in the Kapisa and Parwan provinces, respectively. Kabul, Logar and Wardak provinces are less cattle populated compared to Kapisa and Parwan. In 2012-13, about 13,625,000 m³, 11,474,000 m³ and 10,757,000 m³ of biogas could be generated in these provinces respectively.

The total biogas potential in the central zone of Afghanistan in 2012-13, 2014-15 and 2016-17 was 86,769,319, 88,506,691 and 86,610,419 m³, respectively. Table IV shows a 2% increase from 2012-13 to 2014-15 and back 2.14% decrease from 2014-15 to 2016-17 as it was in the cattle population and dry matter recoverable of the cattle manure.

A double burner biogas stove consumes 0.44 m³ of biogas per hour and a biogas lamps consumes 0.14 m³ of biogas per hour [8]. For an eight-member family In Afghanistan, the average family size is 7.4 persons [17] about 4.44 m³ of biogas will be required per day (4 lamps for 4 hours per day per family and one double gas burner for 5 hours per day per family). The estimated biogas of 2016-17 could be enough for 53,443 families of the central zone of Afghanistan or in other words, 53,443 family size biogas plants could be constructed in the central zone of Afghanistan in that year. From these 8,329 biogas plants could be constructed in Kabul, 14,575 in Parwan, 16,784 in Kapisa, 7,067 in Logar and 6,625 in Wardak province of Afghanistan. The usage of biogas can help in reduction of CO₂ emission, and decrease the import of LPG. On the other hand, the families can save money and enjoy clean fuel usage and better health.

E. Annual Biogas Energy Potential

The annual biogas energy potential is estimated from the annual biogas potential of cattle manure and the biogas calorific value, discussed in the previous sections.

In central zone of Afghanistan, the biogas potential in 2012-13, 2014-15 and 2016-17 was 86,769,319, 88,506,691 and 86,610,419 m³, respectively. With a calorific value of 20 MJ per m³ [14], the estimated biogas energy potential of cattle manure in the mentioned years was 1,735,1,770 and 1,732 TJ, respectively, which shows a 2% increase from 2012-13 to 2014-15 and back a 2.14% decrease from 2014-15 to 2016-17. From the five provinces of the central zone, the highest biogas energy could be generated in the Kapisa province (about 544 TJ in 2016-17) followed by Parwan province (about 472 TJ in 2016-17), Kabul province (about 272 TJ in 2016-17), Logar province (about 229 TJ in 2016-17) and Wardak province (about 215 TJ in 2016-17).

Table V shows the annual biogas energy potential in the five provinces of the central zone of Afghanistan in the three selected years.

V. TECHNOCO-MONOMIC ANALYSIS OF BIOGAS PLANT (A CASE STUDY)

For this case study, a dairy was selected in Kabul province. Considering the environmental situation, material availability and experts in construction, DSAC-Model biogas plant was considered suitable among the other types
of the plants like Janatha, Deenbandhu and floating drum. About 24 cattle were farmed in the dairy selected for this study. The required parameters of the cattle manure were measured on sit in December, 2018. Based on the cattle population and their manure generation potential, the techno-financial analysis of the identified suitable biogas plant was carried out. The DSAC-Model biogas plant was designed based on the design method described in section B of methodology. For this case the dairy needs 24 m³ digester which costs about 1,949 USD. By considering the number of cattle, the daily biogas generation of the plant would be 9 m³.

To find the serviceability of the daily generated biogas, biogas technologies and their burning rate are required. In this case, biogas cook stoves and lamps are focused. A double burner biogas stove consumes 0.44 m³ of biogas per hour and a biogas lamps consumes 0.14 m³ of biogas per hour [8]. In Afghanistan the average family size is 7.4 people [17]. In this case, one double burner biogas stove for 5 hours daily cooking and 4 biogas lamps for 4 hours in the night was assumed for a family of 8 members. Based on the above parameters, the family requires 2.24 m³ of biogas for daily cooking and 2.2 m³ of biogas for lighting and its total daily biogas requirement is 4.44 m³. As the daily biogas generation potential is 9 m³, so it can fulfill the cooking and lighting requirements of two families of 8 members or a single family of 16 members in the central zone of Afghanistan. To find the annual benefit of the biogas plant, it is required to find the unit cost of biogas generated from the biogas plant. The unit cost of biogas can be estimated from its equivalent fuelwood or LPG. 1 m³ of biogas equals to 3.47 kg of fuelwood or 0.45 kg of LPG [8]. As the biogas potential of the plant is 9 m³ daily and 3,285 m³ per year, which equals to 11,398.95 kg of fuelwood or 1,478.25 kg of LPG per year. In Kabul, the cost of fuelwood was 8.63 Afgh per kg (0.15 USD per kg) and the cost of LPG was 45 Afgh per kg (0.66 USD per kg) in December, 2018. Based on the fuelwood cost, the estimated cost of biogas is 98,372.94 Afgh per year (1,710 USD per year) and based on the LPG cost the estimated biogas cost is 66,521.25 Afgh per year (978 USD per year). Here we will take the biogas cost based on the LPG cost 66,521.25 Afgh per year (978 USD per year), which is the annual revenue for the biogas plant owner. Based on the plant type and construction, the life time of the plant is assumed 20 years. After the first year 4.83 percent main inflation rate is applied to the annual cost of the biogas [18].

The financial analysis of the biogas plant is based on the investment in the biogas plant, serviceability period, annual revenue, inflation rate, corporate taxes and interest rate in Kabul, Afghanistan. The total investment for the 24 m³ DSAC-Model biogas plant is 132,533Afgh (1,949 USD) and the annual biogas revenue is 66,521.25 Afgh per year (978 USD per year) which is interested by 4.83 percent mean inflation rate of Afghanistan every next year. The corporate taxes rate is 20 percent [19], and the interest rate is 15 percent in Afghanistan [18]. Based on these parameters, the net present value (NPV), benefit to cost ratio (B/C), internal rate of return (IRR) and the discounted payback period (PP) of the biogas plant are estimated. The estimation method, described in section C of the methodology is used for analyzing these parameters and are shown in Table VII. As all these indicators are in the acceptable ranges, therefore the investment in the biogas generation from cattle manure in the central zone of Afghanistan is beneficient.

<table>
<thead>
<tr>
<th>Financial parameters</th>
<th>Values</th>
<th>Acceptance standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV</td>
<td>2,664.6 USD</td>
<td>NPV &gt; 0</td>
</tr>
<tr>
<td>B/C</td>
<td>2.37</td>
<td>B/C &gt; 1</td>
</tr>
<tr>
<td>IRR</td>
<td>33%</td>
<td>IRR &gt; MARR (15%)</td>
</tr>
<tr>
<td>PP</td>
<td>4.09 Years</td>
<td>PP &gt; Economic life time</td>
</tr>
</tbody>
</table>

VI. CONCLUSION

This study was completed with the achievement of two main objectives. The first objective was to assess the biogas energy potential of cattle manure in the central zone of Afghanistan. In the central zone of the country, the total cattle population was 634,524, 647,229 and 633,362 head of cattle in 2012-13, 2014-15 and 2016-17, respectively. Based on the manure parameters determined from the field and experiments shown in Table II, about 834,320, 851,026 and 832,792 ton of dry matter recoverable could be generated in the mentioned three years, respectively. By using a biogas digester, about 86,769,319, 88,506,691, and 86,610,419 m³ of biogas could be generated in 2012-13, 2014-15 and 2016-17, respectively. The amount of generated biogas is equivalent of 1,735, 1,770 and 1,732 TJ of energy in the mentioned years, respectively.

The second objective of the study was to analyze techno-economic aspects of the biogas utilization in the central zone of Afghanistan. From the field observations, it was noted that biogas plants are not currently used in the central zone. For the evaluation of biogas utilization in the zone, a dairy farm was selected in Kabul province. Based on the cattle population in the dairy (24 cattle) and manure parameters, it was determined that about 9 m³ per day (3,285 m³ biogas per year) of biogas can be generated in a 24 m³ DSAC-Model biogas digester. By comparing biogas energy value from the equivalent energy of LPG, it was determined that the generated biogas has value of 66,521.25 Afgh per year (978 USD per year). The per day generated biogas (9 m³) in the mentioned dairy farm could be enough for lighting and cooking requirements of a single family of 16 members or two families of 8 members. For central zone situations, various biogas plant types of the neighboring countries were discussed and among them, the DSAC-Model biogas plant was considered suitable and its techno-financial analysis was carried out for the mentioned dairy case. The techno-financial analyze result was quite attractive, for this case the NPV was 2,664.6 USD, B/C 2.37, IRR 33% and the discounted payback period (PP) was 4.09 years (4 years and about one month). As all these financial indicators are in the acceptable range, therefore the biogas generation with DSAC-Model of plant is beneficent and attractive in the central zone of Afghanistan.

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