

# **A Biogas Decision Support System Tool**

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## **ABSTRACT**

The importance that renewable energy sources are having nowadays is tremendous. Among them perhaps one of the most important ones is the generation of Biogas. Its current cost is very competitive with Natural Gas regular prices, electricity and other renewable. In this work we present a Biogas generation Decision Support System application that allows for a very simple calculation of the amount of Biogas to be generated from a given organic material. The other way around is also considered. .

The general background is discussed, with emphasis on the theoretical background discussing the amount of Biogas a digester can provide. Then, we present the application designed using Microsoft Visual Basic application we developed. Sample calculations are shown, with simple user friendly screens. Our calculations are validated against current costs of natural gas. The subroutine presents very good results for applications of different biomass sources. Moreover, the user can update the database used with different new raw materials sources.

## **Keywords**

Renewable Energy. Biomass, Biogas, Bio-Fertilizer

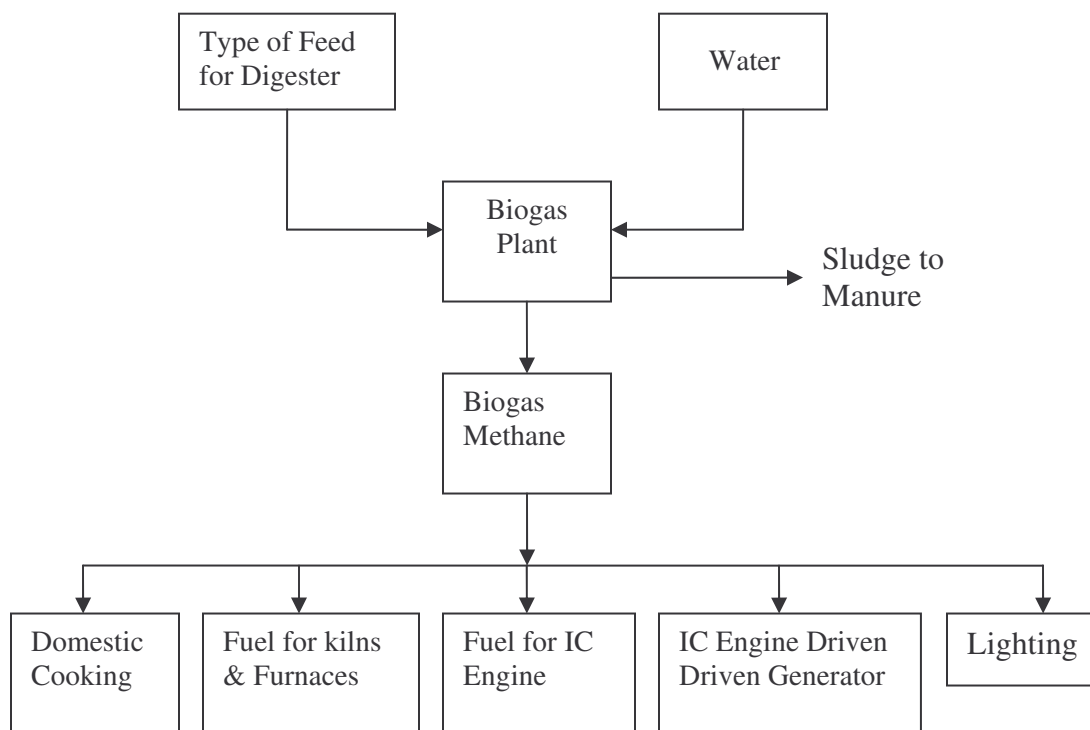
## **1. INTRODUCTION**

Biogas is a renewable energy source. It is a bio-fuel generated by the fermentation process of biomass also known as anaerobic digestion.

An anaerobic digestion process happens in absence of oxygen, and bacteria break down the carbohydrates that are in the waste products. This releases Biogas which is a mixture of methane ( $\text{CH}_4$ ), sulphidric acid ( $\text{H}_2\text{S}$ ), carbon dioxide ( $\text{CO}_2$ ), and hydrogen ( $\text{H}_2$ ) gases. The content of methane ranges from 50 to 80%, and it depends on the kind of substrate and on operating conditions. Content of methane in biogas can be increased by further treatment (drying, desulphurization, etc.). Carbon dioxide is the second major component. Its content ranges from 20 to 40% in biogas and, with  $\text{H}_2\text{S}$ , is among the first with to be generated. The uses of the gas are many, ranging from solving a potential health problem, to the generation of electricity by the use of an Otto cycle motor. A description of Biogas generation and uses is shown in Figure 1.

## **2. GENERAL BIOGAS USAGE**

Biogas finds a great usage in many sectors. Biogas can be used extensively in large and small scale industries using Internal Combustion (IC) engine driven generators. Biogas methane acts as an apt fuel for the IC engine. IC engine, in turn, find various industrial applications for their usage to drive shaft for fans, blowers, pumps and compressors. Cogeneration and processing heat and electricity are also some direct applications of IC engine. Apart from the industrial usage, IC engine can be used in vehicles, thereby a great alternative for non-renewable fuel sources.



**Figure 1: Energy Route of Biogas**

In addition, biogas can also be used to drive gas turbines and co-generating shaft horsepower. The direct combustion of biogas can be used for steam generation, water and space heating, absorption cooling and heating, dryers, etc. Power home appliances using gas as fuel, also find a use for cooking, lighting, etc. Biogas can be easily provided through pipeline becoming a cost effective and environmentally friendly alternative.

The use of this renewable energy source can go to fuel for kilns and furnaces; which are an important part of many industries like metallurgical extraction, and cement manufacturing. It also can be used as a fuel for farmers to provide heat for digesters, and electricity. In case when electricity is plentiful, farms can sell the electricity back to the utility company. As a matter of fact, now a day's in the United States the gases coming out from landfills are being harvested, and filtered to take their biogas generated by natural anaerobic processes, and use it to run power generators. The companies involved in this business sell their power to the local grid. An interesting new idea on the use of Biogas is to transport it to far places in the form of compressed or liquefied gas, especially in places where gas pipelines are not available..

However, one of its most important contributions is in the health area. Since most of the biomass used comes from waste, as is manure or food processing residues, the use of it as raw material for biogas and bio-fertilizer generation, comes to solve a health problem. This is really a twofold solution. On one end is the elimination of an infectious focus of diseases, and secondly the use of waste to generate energy and a fertilizer, a "biofertilizer". The last one has shown to be, depending on the source of the waste, a great organic fertilizer since its N-P-K levels (Nitrogen, Phosphorous and Potassium, respectively). This biofertilizer help to provide additional nutrients to the soils, to recover some, and avoids the use of chemical fertilizers.

As a summary, the advantages that Biogas presents are summarized below:

- The most evident advantage of biogas is that it provides a renewable source of energy and can be used directly for heating purposes or generating electricity. This reduces the pressure on the non renewable and potentially more harmful and toxic resources like coal, petroleum, etc.
- The risk of diseases diminishes greatly as the digested waste products from the process of bio gas creation are considerably less toxic and are infested with less quantity of parasites and pathogens as compared to the waste in the original form.
- Biogas digesters are excellent in combating odor and other health problems (no more infectious focus). Although these benefits are difficult to quantify, biogas digesters can provide an effective solution to odor problems and improve community relations.
- The digested solids recovered from the biogas digesters can be used as bedding material after drying them well. It is also widely used in farms for animals feeding (mixed with hay, for example).
- The digested material can also be used as a fertilizer which is richer in nutrients like nitrogen, phosphorus and potassium and hence can substitute the toxic commercial fertilizers.

On the other hand, the disadvantages that Biogas could have are described below:

- Biogas creation requires warm, wet and dark conditions and thus it proves to be less beneficial in colder environments where a large amounts of gases need to be burned to maintain temperatures conducive to anaerobic digestion. This reduces the cost efficiency considerably.
- The initial cost to setup a biogas digester is very high and its components like the digesters, biogas rated generators, biogas fired boilers to warm the digesters require continuous support and maintenance.
- Biogas is usually of much lower quality than natural gas. It is often between 30-50%  $\text{CO}_2$ , which reduces the energy per cubic feet by up to a factor of 2 when compared to natural gas. In addition, water and other unwanted gasses such as  $\text{H}_2\text{S}$  are components of biogas which frequently need to be removed.

### **3. THE BIOGAS GENERATION DSS**

In the search for alternatives for the use of renewables, Biogas is certainly one of them. However, there is no easy way to have a good estimate of the potential Biogas production. Hence, there is a need for some basic decision support system (DSS) application, which will give users the result which they are looking for. The objective is provide a robust results, with the minimum input and time usage on performing the calculations.

The Biogas application was designed using Microsoft Visual Basic. It gives exact solutions to common issues. It serves as a basic application program which reduces the tedious math problems and thus saving time by giving an easy complete output. In addition, the tool helps, beyond the back of the envelope calculation, to decide if the user should pursue the investment on this project.

The Biogas application is a very user friendly one and gives the user a number of options that will be the form of the output. By just selecting a biomass source from a list of options and providing the amount of waste source, the user can know the amount of Biogas (in MMBtu/ hr) that source will generate. The other way around is possible too, this is, if we know how much Biogas we need to generate then this application calculates the required quantity (mass) of waste source selected. The Biogas Application also gives the user the freedom to self-maintain the database. This can be done by adding a "new source" of organic waste which they wish to use as an input to the digester.

In this section we provide the details about the forms that the user may encounter while using the application. There are three windows, the welcome window, the Main form and Add Source form, also one worksheet form named as Result sheet gives the detailed result on a worksheet. Each form is described here in detail. All the option buttons on every form are explained in detail through screenshots of the application.

We start with the Welcome screen which has two command buttons, shown in Figure 2. The other windows and capabilities are shown later on in this work.

**Start:** When you click on this it will load the Welcome form.

**Exit:** This button closes the application and saves all the work that the user has done.

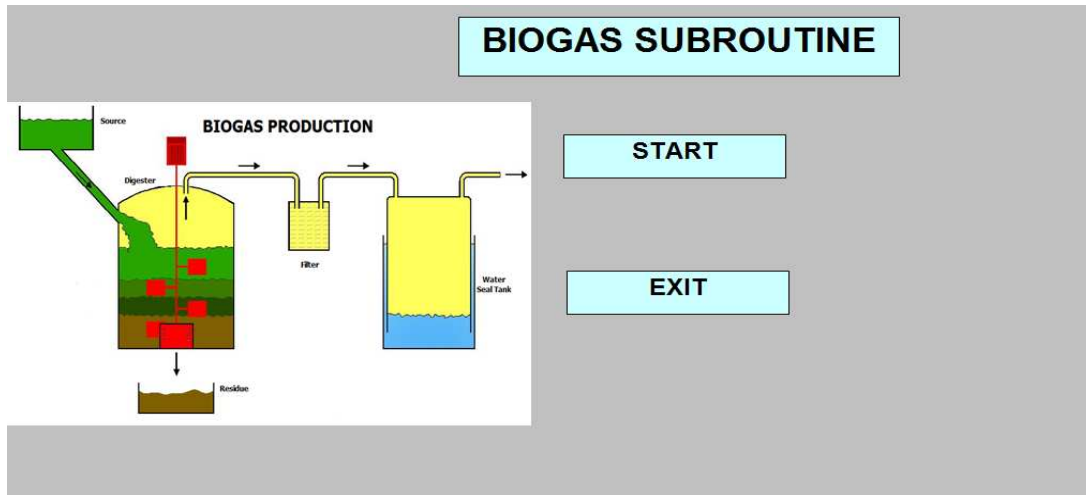


Figure 2: Welcome Screen

### 3.1 THE WELCOME WINDOW

This form as shown in Figure 3 gives the user two options to start with:

- Whether the user wants calculate the amount of Biogas produced (in MMBtu/hr) by giving Quantity of organic material source as an input, or
- The user wants to calculate the Quantity of Source required (Kg) to generate a given Amount of Biogas.

What do you want to do?

☐ Calculate Biogas produced (MMBtu/ hr)

☐ Calculate Quantity of Source required to generate specific Biogas (Kg)

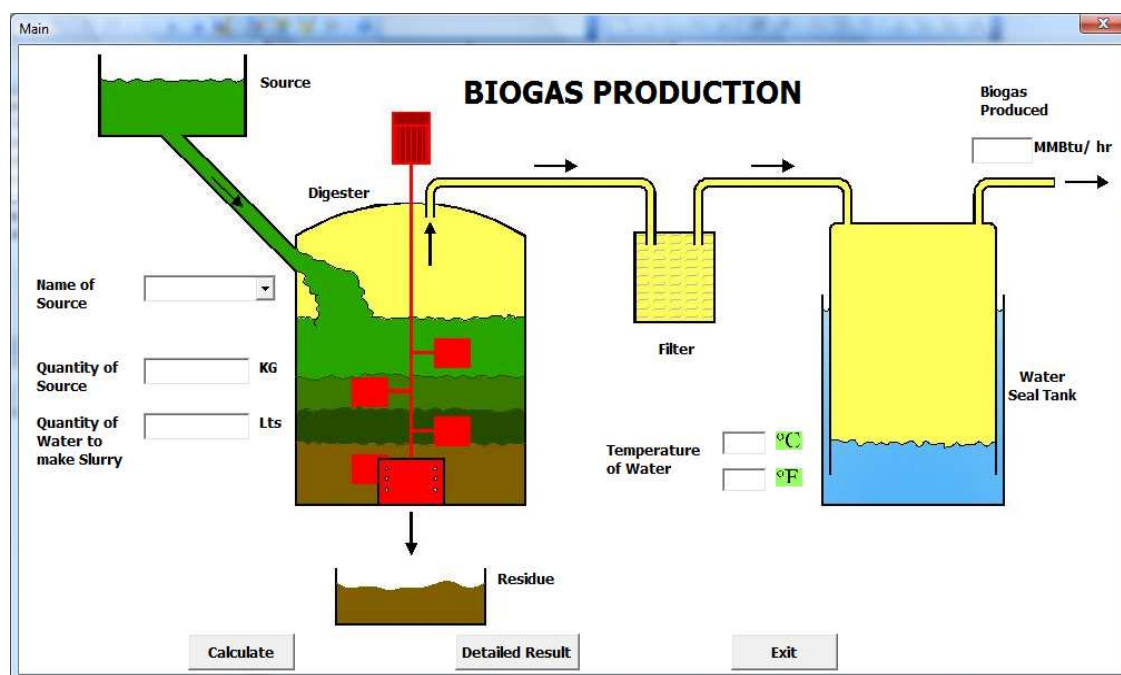
Next Exit

Figure 3. Welcome Form

After selecting either of the options, the user clicks in the "Next" button. The application shows then the Main form shown in Figure 4, which is discussed in detail in the next section. At this point, if the user wants to exit the application, the "Exit" button is just a click away, taking the user back to the "Welcome" window.

### 3.2 THE MAIN WINDOW

This form, shown in Figure 4, presents a schematic diagram of Biogas Production and allows the user to select the



**Figure 4: Main form of Biogas Subroutine**

source of organic material, and provides input depending on the option selected in the Welcome form. This window has three command buttons:

**Calculate:** After the user selects the source and has provided input in either one of the text boxes, depending on the option selected in the Welcome form, the not needed input data will be blocked. The calculations are done immediately and the user can see the his results on the form itself.

**Detailed Result:** This button takes user to a Result worksheet shown in Figure 5, where he can print out the results in a Word document format.

**Exit:** Take the user back to the Welcome screen.

### 3.3 THE RESULT FORM

This Result sheet provides the user with two additional command buttons:

**Print:** By clicking on this button the user can take a print out of the calculations which he just made in detailed format for further reference.

**Welcome:** Clicking on this command button takes the user back to the Welcome sheet.

**Exit:** Takes the User to welcome form.

The screenshot shows a software interface titled "BIOGAS SUBROUTINE". It features a "PRINT" button in the top right and a "WELCOME" button below it. A large "RESULT" label is centered. On the left, there are two tables: "INPUT" and "OUTPUT".

INPUT	
Source	Cow
Dry Content (%)	17.00%
Methane Content (%)	57.00%
Temperature (°C)	30
Quantity Req'd. (Kg/day)	3000
Amount (kg/day)	10

OUTPUT	
Biogas (kg/day)	203.49
Biogas (MMBtu/hr)	0.337540451
Total Source	300

Figure 5: Result Sheet

This form itself provides Information such as the temperature of the water to be maintained and the Water content to be added to the source to make the slurry.

### 3.4 THE ADDING A BIOGAS SOURCE FORM

While selecting the source of organic material, if the user does not find the desired one in the database then he can select the option "Other" from the drop box list. As soon as the user selects "Other" source it takes him to another form where he can add a new organic source, thus maintaining his own database effectively, as shown in Figure 6. In this form, the Biogas DSS window provides users with two options to select the type of Source:

**Animal excreta:** If this option is selected then an extra data input is needed: the Amount of excreta a particular animal produces in kg/day, or organic source (other). This input, shown in Figure 6 is necessary as it would help by providing the user with the total number of animals needed per day to generate the required amount of Biogas.

**Other Sources:** If the user wishes to enter any other source other than that of Animal excreta then they should select the Other option which hides the Amount in ( Kg/ day/ animal) option.

**Cancel:** This button just simply cancels the current selections, and the user remains in the same window.

The screenshot shows a window titled "Add Source" with a close button (X) in the top right corner. Inside the window, under the heading "Select Source type", there are two radio buttons: "Animal excreta" (which is selected) and "Other". Below this, there are four input fields labeled "Name of Source", "Water Content (%)", "Methane Content (%)", and "Amount (kg/day/animal)". At the bottom of the window, there are two buttons: "Add" and "Cancel".

Figure 6: Add Source (Animal Excreta)

The screenshot shows a window titled "Add Source" with a close button (X) in the top right corner. Inside the window, under the heading "Select Source type", there are two radio buttons: "Animal excreta" and "Other" (which is selected). Below this, there are four input fields labeled "Name of Source", "Water Content (%)", "Methane Content (%)", and "Amount (kg/day/animal)". At the bottom of the window, there are two buttons: "Add" and "Cancel".

Figure 7: Add Source (Other)

#### 4. THE UPGRADABLE DATABASE

As we discussed earlier, this application can be used to calculate Biogas produced from a given source, its amount or Quantity of source provided. The other way around, also possible, is to calculate the Quantity of source from amount of Biogas generated. The calculations involves the following assumptions:

**Temperature** of water to be maintained as constant: 30°C

**Water** (in weight percentage) to be added to the source to make slurry: 85%

In Tables 1 and 2 the average yields of excreta and the solid content in common fermentation materials coming from rural areas, respectively, is shown. Table 3 shows the percentage of Biogas to be generated.

Table 1: Average yield of Dung from Animals, Birds, and Humans (approximately)

Animal	Excreta per animal per day (kg)
Sheep/ goat	4
Cow	4
Ox	12
Buffalo	15
Pig	2
Poultry bird	0.2
Human Being	0.5
Horse	11



**Table 2: The total solid content of common fermentation materials in rural areas (approximately)**

Materials	Dry matter content (%)	Water content (%)
Dry rice straw	8	1
Dry wheat straw	8	1
Corn stalks	8	2
Green grass	2	7
Human excrement	2 0	8 0
Pig excrement	1	8
Cattle excrement	1	8

**Table 3: Biogas Materials and their Methane Content**

Materials	Methane content ( % )
Barnyard Animal Manure	50 - 60
Green grass	70
Wheat straw	59

## 5. CALCULATIONS

As an example of calculations, we will try to find out the amount of biogas that can be generated from a given amount of raw material. Let's consider the following example.

### **Input Data:**

- Type of Source: Cow dung
- Cow dung per day per animal = 10 kg/ day
- Quantity of Source = 3000 kg/ day
- Total Number of Source =  $3000 / 10 = 300$
- Total Cow dung collected = 70% of 3000 = 2100 kg/ day

Approximately 70% dung is collected for feeding into the Biogas plant. The remaining 30% gets lost in the fields during cow grazing

- Dry solid Cow dung =  $2100 * .17 = 357$  kg/ day

### **Output Data:**

- Biogas produced =  $357 * .57 = 203.49$  kg/ day  
 (Methane content in Cow dung is approximately 57%)

$$1 \text{ kg/ day} = 42000 \text{ KJ/ day}$$

$$1 \text{ KJ/ day} = (3600/ 3412.3) \text{ Btu/ day}$$

$$1 \text{ Btu/ day} = 1/24 \text{ Btu/ hr}$$



Finally, the Biogas produced is  $337,540.5 \text{ Btu/hr} = 0.34 \text{ MMBtu/hr}$

Since a biodigester can run more efficiently, and have a much more effective impact, if they operate all year long (i.e., 8,760 hr/yr). Then, the annual energy production (EP) will be:

$$\text{EP} = 0.34 \text{ MMBtu/hr} * 8,760 \text{ hr/yr} = 2,978.4 \text{ MMBtu/yr}$$

From here the results can be extended to the potential Cost Savings (CS). If we consider the current cost of Natural Gas at about \$20 per each million Btu (\$20/MMBtu), then:

$$\text{CS} = 2,978.4 \text{ MMBtu/yr} * \$20/\text{MMBtu} = \$59,568/\text{yr}$$

This estimated savings, under the conditions established for these calculations are not far from reality, and show the great economic potential that Biogas has as a renewable and very competitive energy source. A natural consequence of this study will be to consider the implementation (building) cost of a Biodigester system. However, that depends on local construction materials and labor costs. In general it is expected that paybacks will reach the range of 2 to 3 years.

## 6. CONCLUSIONS

Thus this application allows user to maintain his/ her database by adding a source which he desires as the source of input to the digester. This application allows user to know the Amount of Biogas produced/ Quantity of source required by the click of a button and also by avoiding all the calculations involved in the process. The application also provides user with the ability to take print out of the detailed result for further reference.

## REFERENCES

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