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**Techno-Financial Analysis of Bio-Compressed Natural Gas as an Alternative Cooking Fuel: A Case Study of Gandaki Urja**

by

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# APPROVAL PAGE

The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled “**Techno-Financial Analysis of Bio-Compressed Natural Gas as an Alternative Cooking Fuel: A Case Study of Gandaki Urja**” submitted by Sanjay Rajbhandari, PUL074MSTIM014 in partial fulfillment of the requirements for the degree of Master of Science in Engineering in Technology and Innovation Management.

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# ABSTRACT

Nepal generates around 2500 tons of solid waste each day. These wastes are collected from the sources and dumped directly at different landfill sites throughout the country without proper segregation and scientific methods. These unscientific dumping of the wastes, emissions from the combustion of petroleum products and excessive use of chemical fertilizers in the agricultural field are mainly responsible for spreading diseases in human beings and creates huge negative impacts in the whole ecosystem while playing the major role in rapid increasing national trade deficit.

Thus, our research emphasize on the technical and financial aspects of the largest BioCNG plant in Nepal, Gandaki Urja Pvt. Ltd. with a focus on the technical process of waste collection, anaerobic digestion, gas purification, compression, storage and fertilization. This study also includes a commercial viability and future of BioCNG as an alternative fuel.

From the field study of Gandaki Urja, it is found that the total waste processing capacity of the plant is 45 TPD leading to the formation of 2500 m3 of raw biogas, 1125 Kg of BioCNG and 2000 Kg of organic fertilizer per day. Due to the covid pandemic and lockdown, the demand of gas and fertilizer were reduced drastically. This minimized the feedstock in the plant to 18 TPD leading to generation of 1014 m3 of raw biogas, 456 Kg of BioCNG and 1000 Kg of organic fertilizer per day. Organic fertilizer from biogas plant has proved to be high quality manure rich in humus with pH 7.78, moisture 30%, nitrogen 1.5%, phosphorous 0.5% and potassium 1.5%. About 4.8 GJ/day energy is required for the complete production and storage of BioCNG and organic fertilizer which is about 20% of the total energy generated at 18 TPD capacity and about 9% of the full capacity of 45 TPD. At 18 TPD capacity, produced BioCNG can replace 518 Kg, 495 L and 570 L of LPG, diesel and petrol respectively. Similarly, 1152 Kg, 1102 L and 1268 L of LPG, diesel and petrol respectively at 45 TPD capacity. From the production and use of BioCNG, LPG has been replaced for cooking purpose. This will reduce around 320 TPY of CO2 emission with 18 TPD capacity and 715 TPY with 45 TPD capacity. Similarly, comparing with diesel and petrol 1086 TPY and 1018 TPY CO2 emission will be reduced at full capacity.

The financial feasibility of the project was also assessed taking 10 years as the analysis period. The total yearly sale revenue projected is NRs. 58.993 Million at 100% capacity. The annual net profit of the company is calculated to be Rs. 22,682,125.00. Taking the 40% government subsidy in capital expenditure, with annual profit of Rs. 22,682,125.00, the payback period will be in 7th yr of selling of products. Taking without 40% government subsidy in capital expenditure, with annual profit of Rs. 22,682,125.00, the payback period will be in 11th yr of selling of products. The debt/equity/subsidy ration was found to be 32%/28%/40%.

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Sanjay Rajbhandari

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# LIST OF ABBREVIATIONS

AD Anaerobic Digestion

ADB/N Agricultural Development Bank of Nepal

AEPC Alternative Energy Promotion Center

AMSL Above Mean Sea Level

BioCNG Bio-Compressed Natural Gas

BSP Biogas Support Programme

CBS Central Bureau of Statistics

CH4 Methane

CO2 Carbon dioxide

CSTR Continuous Stirred Tank Reactor

GHG Green House Gas

GJ Giga Joule

GoN Government of Nepal

h Hour

H2O Water

H2S Hydrogen Sulphide

IRR Internal Rate of Return

Kg Kilogram

kWh Kilo Watt Hour

LPG Liquefied Petroleum Gas

m3 Cubic Meter

MC Metropolitan City

mg Milligram

MJ Mega Joule

MSW Municipal Solid Waste

N2 Nitrogen

Na2S Sodium Bisulphide

NaHS Sodium Sulphide

NaOH Sodium Hydroxide

ND Not Detected

NH3  Ammonia

NPR Nepalese Rupees

NPV Net Present Value

O2  Oxygen

oC Degree Centigrade

PMC Pokhara Metropolitan City

ppm Parts Per Million

PRS Pressure Regulating System

SCADA Supervisory Control and Data Acquisition

SDG Sustainable Development Goals

SMC Sub-Metropolitan City

SNV/N Netherlands Development Organization-Nepal

SWM Solid Waste Management

TPD Tons per Day

TPY Tons per Year

TS Total Solid

VS Volatile Solid

# CHAPTER ONE: INTRODUCTION

## Background

Living beings have used resources from the nature directly or indirectly for their well-being. The remaining products are thrown away after the use. These unwanted and unused materials are known as waste. These wastes can be in solid, liquid or gaseous form. Thus, waste can be defined as “domestic waste, industrial waste, chemical waste, health institution related waste or harmful waste, waste which cannot be used presently, thrown away materials in either solid, liquid or gaseous phase which damages the environment and materials” (Solid Waste Management Act, 2011). These wastes need to be disposed systematically and scientifically. With the advancement in the urban life, waste began to accumulate in the living areas that led to negative impact on both human and nature.

Waste management has become major environmental problem in many urban areas, including cities of Nepal. The rapid growth in urban population and lifestyle has increased municipal waste generation. The use of products that generate hazardous wastes, medical, industrial, construction and chemical wastes from hospitals, clinics, industries and business also contribute to pollution and public health hazards in the localities. Therefore, waste has become a major concern for the urban areas of developing countries.

Solid waste management (SWM) can be defined as the process of management of solid waste scientifically so as to minimize their adverse effect on nature and humans and maximize their potential for reuse, recycle and reprocess. More specifically, SWM is “associated with the generation, storage, collection, transfer and transport, processing and disposal of solid waste in according with the best principles of public health, economics, engineering, conservation, aesthetics and other environmental conservation” (Tchobanoglous & al., 2014).

Every country has now become aware about consequences of improper waste disposal. Government of Nepal (GoN) is responsible and fully committed for the proper management of the solid wastes in the country. GoN has taken actions in managing its environment by establishing and formulating different legislatives frameworks and policies for waste management which are listed below.

1. Solid Waste Management National Policy, 2053 (1996)
2. Solid Waste Management Act, 2068 (2011)
3. Local Government Operation Act, 2074 (2018)
4. National Climate Change Policy, 2076 (2019)
5. Environment Protection Act, 2076 (2019)
6. Sustainable Development Goals (SDGs), 2016-2030

According to the GoN report on “Waste Management Baseline Survey of Nepal 2020”, Central Bureau of Statistics (CBS) in 2019/20 had conducted the waste management baseline survey which covered 271 municipalities of Nepal. Some of the major findings of the survey are listed below.

1. Major categories of wastes generated from those municipalities were: organic waste (agricultural and forest waste, kitchen waste, textile and paper waste), inorganic waste (glass, rubber, plastics, metals and minerals) and other wastes (waste apart from the above).
2. The average total waste generated per municipality was 2232.7 MT annually in the year 2075/76.
3. The composition of waste was: organic (54%), inorganic (33.3%) and other waste (12.7%).
4. Among the various sources in metropolitan city (MC), the quantity of waste collection were: household (15.8 TPD), business complex (7.7 TPD) and educational institution (4.7 TPD).
5. In sub-metropolitan city (SMC) and municipalities, the household waste generated accounted for 3.3 TPD and 1.4 TPD respectively.
6. Only 12 i.e. 4.4% (1 MC, 1 SMC and 10 municipalities) of the total municipalities under study were using transfer station for waste management.
7. Similarly, only 15 municipalities were using various methods for proper management of the waste.
8. The survey revealed three major waste handling methods: piling up waste in landfills by 48.6%, burning waste by 32.1% and piling up waste in river side by 27.4%.
9. Only 30 (2 MC, 5 SMC and 23 municipalities) were recycling waste.
10. Out of total waste generated, only 4.1% were recycled.
11. Total of 114 municipalities were using landfills and 117 were not using landfills.
12. Almost all 257 municipalities were expecting technical helps and funds from the provincial and federal governments (GoN, 2020).

Figure 1: Composition of the waste generated in local governments

Figure 2: Sources and quantity of waste generated in metropolitan city

As urban population densities increase and usable land is limited the management of solid waste has become a growing concern in Nepal. Although some small urban centers were declared as municipalities, they lack different infrastructural, technical and financial resources to solve the burning problems of solid waste management. With the increasing public awareness about safe food, good health, clean environment and sanitation, solid waste management has now become the priorities of the municipalities in Nepal. For managing the waste, municipalities are expressing their interest in developing final disposal system and are also promoting the different ways of waste reduction, reusing and recycling among the communities for healthy life and green environment.

## Pokhara metropolitan city profile

### General information

On 2073 Falgun 28, the then Lekhnath Municipality and Pokhara Sub-Metropolitan City were merged to form the new Pokhara-Lekhnath Metropolitan City to become the largest metropolitan city of Nepal with the area of 464.24 Km2. Recently, it has been renamed as Pokhara Metropolitan City (PMC) with total numbers of 33 wards. It also includes additional Mauja, Chapakot, Puranchaur, Kaskikot village development committee (VDC), wards 3 to 9 of Bhadaure Tamagi VDC, wards 1, 4 to 9 of Majhthana VDC and wards 1 to 5 of Kalika VDC (GoN P. M., 2074).

### Land use pattern

Pokhara Metropolitan City has become the one of highest urbanizing city of Nepal. The population growth and high migration rate has contributed to rapid urbanization. In 1995, the urban area coverage was 1.75% which has increased to 4.78% in 2010 while cultivated land has diminished from 50.2% to 39.5% during the same period in the city. Regardless of this urbanization, overall forest coverage has increased slightly from 38.77% in 1995 to 49.93% in 2010 (Regmi & al., 2017).

### Demography

The total population of the metropolitan city is 4,13,934 with 2,01,107 males and 2,12,827 females and population density of 892/km2 as per census of 2011. Ward no. 27 having the highest population of 26,752 and ward no. 20 having the least population of 4,022 (GoN P. M., 2074).

Table 1: Pokhara metropolitan city profile

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| S.N. | Local Government | State | Area | Population | Density | No. of Wards |
| 1 | Pokhara Metropolitan City | Gandaki | 464.24 Km2 | 4,13,934 | 892/ Km2 | 33 |

###

### Solid waste management system

Pokhara Metropolitan City is second largest in terms of population with 4,13,397 people. PMC generates 200 Metric Tons of waste every day and is expected to rise. PMC has collection efficiency of 95% and spends nearly 83.5 corers NPR annually for solid waste management. For waste collection door to door service and daily road pick-up services has been practiced by using tractor, tipper, rickshaw and compactor which is disposed in landfill site 12km away from the city. It consists of a landfill area, treatment area, buffer zone, internal road, composting area and other infrastructure with the coverage area of 200 hectors. Some social groups like Gyan Margswatantra Mahila Samuha are focused on street sweeping, community clean up campaigns, waste collection, transportation, composting and recycling whereas Samidaik Sewa Kendra and Prahari Sewa Kendra are working on street clean up, installation of filter pond and controlling water hyacinth in Fewa lake (SWMRMC, 2005).

Table 2: Waste management system of PMC

|  |  |  |  |
| --- | --- | --- | --- |
| S.N. | Waste Generation | Collection Efficiency | Annual Expenditure |
| 1 | 200 TPD | 95% | corers NPR |

## Industry overview

Few organizations are converting organic waste to BioCNG for cooking purpose as substitution of LPG. Since last 4 years (2017-2021), BioCNG were introduced in Nepal for institutional cooking and electrification purposes. Gandaki Urja Pvt. Ltd. and Envipower Energy and Fertilizer Pvt. Ltd. were introduced in Nepal for cooking purpose as substitution of LPG. While, Khilung Kalika Agro Farm Pvt. Ltd. generates BioCNG for electricity production of 350 kW. These industries uses agro and livestock waste for the production of BioCNG.

Gandaki Urja Pvt. Ltd., is a private company established in 2074 B.S and registered in Pokhara. As being the environmentally friendly and most suited form of company in the context of Nepal, 40% grant of total cost has been provided by Nepal Government. The company is owned and managed by a group of young entrepreneurs and energy experts. The company operates Nepal’s largest commercial scale BioCNG plant of 45 TPD of organic waste digestion which converts into 2700m3 biogas or 1500 Kg of BioCNG and 2 MT of organic fertilizer daily. The plant uses multiple feed Continuous Stirred Tank Reactor (CSTR) digester to produce biogas from cow/buffaloes dung, pig manure, poultry litter and vegetable/agricultural wastes. The bio-gas thus produced is then purified and compressed to form BioCNG which is then compressed and filled into suitable cylinders and sold as a substitute for LPG. In addition, the plant also produces enriched organic fertilizer as a valuable byproduct (Urja, 2074).

Table 3: Company profile Gandaki Urja Pvt. Ltd.

|  |  |  |
| --- | --- | --- |
| S.N. | Particulars | Features |
| 1 | Name | Gandaki Urja Pvt. Ltd. |
| 2 | Company Address | Pokhara Metropolitan City, Ward No. 9 |
| 3 | Plant Address | Majuwa, Pokhara Metropolitan City, Ward No. 32 |
| 4 | Email address | gandakiurja@gmail.com |
| 5 | Contact No. | 061-620800 |
| 6 | Plant Capacity | Waste: 45TPDGas: 1.2 TPDFertilizer: 2 TPD |
| 7 | Technology | Continuous Stirred Tank Reactor (CSTR) |

## Significance of study

1. Government: Policymakers who make climate change and national economy policies will see how use of locally available organic waste converted into BioCNG through engineering processes can be used to mitigate the amount of greenhouse gases produced otherwise and use BioCNG as an alternative fuel reducing the dependency on imported fossil fuel. Local government can uses this technology to solve segregation of municipal waste and land-filling problems. This ensure the effective waste management system.
2. Researchers: Researchers and subject matter experts in fields like energy, biotechnology, climate, process engineering etc. will gain new insights into a subject of wide concern.
3. Entrepreneurs: Abundant availability of organic waste as raw materials to convert into BioCNG as fuel has huge possibility for entrepreneurs to start clean tech waste to energy ventures which helps in economic growth of the nation.
4. Farmers: Implementing organic fertilizers could be more economic, easy, and effective than chemical fertilizers and use it to increase income and agricultural productivity.
5. General Population: Climate change and automotive are subjects of general and critical concern. General population will benefit from cleaner transportation, healthier environment and economic and effective use of available resources.

## Problem statement

Nepal generates around 2500 tons of solid waste each day. These wastes are collected from the sources and dumped directly at different landfill sites throughout the country without proper segregation and scientific methods. Also, many of these landfills are located at nearby river banks and open spaces. In addition to this, urban people in the country mainly depend on LPG for cooking purpose. These petroleum products which fulfills our daily energy needs fall under the top three imports in our country. On the other hand, imported chemical fertilizers are used in agricultural fields to increase the productivity of plants. These unscientific dumping of the wastes, emissions from the combustion of petroleum products and excessive use of chemical fertilizers in the agricultural field are mainly responsible for spreading diseases in human beings and creates huge negative impacts in the whole ecosystem while playing the major role in rapid increasing national trade deficit. This research helps to study on technical and financial fundaments of commercialization and adoption of alternative fuel for cooking purpose to reduce reliance on LPG by using BioCNG through compression of methane gas derived from anaerobic digestion of biodegradable waste.

## Research objectives

### General objective

* To analyze the technical processes and financial aspects of BioCNG and fertilizer production from organic waste at Gandaki Urja, Pokhara.

### Specific objective

* To quantify and characterize feedstock available in the plant.
* To calculate quantity of BioCNG and organic fertilizer produced.
* To evaluate carbon emissions reduction from the plant.
* To perform the cost benefit analysis of the plant.

## Limitations

The major limitation of the research are as follows:

1. There are very few prior academic research on use of BioCNG as alternative cooking fuel in Nepal which may lack in focused on the most contemporary and evolving research problem.
2. This study basically focuses on an overview of technical parameters and financial aspects of a single BioCNG plant i.e. Gandaki Urja.
3. The study was conducted only on the month of April which might not give the actual outputs of other months.
4. Due to the corona virus pandemic and lockdown, feedstock were limited to locally available livestock waste, thus running plant at low capacity.

# CHAPTER TWO: LITERATURE REVIEW

This section starts by reviewing the various national and international reports, journal papers, articles related to the study. The study finds out the history on development of BioCNG technology, use of BioCNG as energy source, current status of BioCNG development, framework, policies, theories in Nepal and worldwide. Thus this section helps to understand the past and present status and future possibilities of commercialization and adoption of BioCNG as an alternative cooking fuel to reduce reliance on petroleum fuel through compression of methane gas derived from anaerobic digestion of biodegradable waste.

## History of biogas

The biogas technology dates back a long time. Helmont and Shirley had mentioned about biogas in 1630 and 1667 respectively. “In 1808, H. Davy investigated straw manure in a retort in a vacuum and collected biogas” (Tietjen, 1975). In 1859, the first biogas plant was built at a leper colony in Bombay, India. “In 1895, biogas was recovered from a “carefully designed” sewage treatment system in England which was then used as fuel to light street lamps in Exeter” (Tietjen, 1975). “Later, the biogas production was promoted after the development of microbiology research led by Buswell and others in 1930 to identify anaerobic bacteria and the conditions” (Tietjen, 1975). Gradually, anaerobic digestion (AD) technology were used in small and medium scale in different energy and agricultural field around the world. Small and low-tech digesters were used to generate biogas for different cooking and lighting purposes during 1950s. “In Europe, AD process was used rapidly during and after World War II when energy supplies were reduced drastically” (Meynell, 1976). With the increase in research and construction facilities, China and India are using large high-tech digesters systems with better process for generation of gas and fertilizer. Countries like Sweden, Denmark, Germany, US have the maximize the use of large and commercial scale AD technology for heat and power combined system using organic wastes from different sources. “North and South American countries have also increased their interest in such AD technologies with considerable number of the systems located in, Brazil” (Lettinga & Van, 1992).

## Biogas scenario in Nepal

The history of biogas technology in Nepal dates back to mid-1950s. “In 1955, the first model of biogas technology was introduced in Nepal by Late Father B R Saubolle, a school teacher at St. Xavier’s School, Godavari, and Kathmandu. The system was developed using a 200-liter oil drum with a metallic gas holder” (Karki, Nakarmi, Dhital, Shrma, & Kumar, 2015). During 1970s, national wide promotion of home biogas technology was actively played by Agricultural Development Bank of Nepal (ADB/N) by providing soft loans to the interested households (KC, 2011). The Biogas Support Programme Phase I (BSP I) and gradually BSP II/III/IV was launched during 1992-2003 which lead to construction of more than 2,50,000 plants supported by the Government of Nepal (GoN) and Netherlands Development Organization-Nepal (SNV/N). “By the year 2014, 3,50,000 household plants had been installed in the country. At present the biogas technology is being promoted by Alternative Energy Promotion Center (AEPC)” (Karki, Nakarmi, Dhital, Shrma, & Kumar, 2015).

## BioCNG technology

Bio-gasification has awesome natural benefits compared to petroleum power generation. Coal burning causes adverse human and environmental effects. Concerning the expanding issue of energy and waste problems, biogas derived from organic matter is continuously getting to be a clean generation solution (Holm, J.B, & Seadi, 2009). The different processes used for the production of biogas and its upgrading technology are briefly discussed below.



Figure 3: BioCNG process flow diagram (EESI, 2018)

1. Feeding of organic waste

The feeding raw materials like cow dung, chicken litter, and press mud and vegetables waste are fed in the preparation tank. In the preparation tank water has also to be fed in equal ratio with the raw materials so for that water is taken through water tank which are placed at certain height. The raw materials should be of small size and should be properly mixed with water so an agitator is placed in preparation tank. It dissolves feeder materials clearly with water. The materials collected in the preparation tank is in gel like form and there is provision for sending these to digester through pipeline by the use of feed pump (Ilyas, 2006).

1. Anaerobic digestion

Anaerobic digestion uses the process of fermentation to breakdown organic matter to produce biogas that has high content of methane (typically 50-75%). This reduces the disposed organic waste volume and weight to be land filled. Odors of municipal wastes are eliminated and the emission of carbon dioxide and methane are reduced in the environment. Hydrolysis is the first stage where carbohydrates, proteins and lipids are converted into glucose, glycerol and pyridines. During acidogenesis, sugar, amino acid and fatty acids are converted into acetic acids, carbon dioxide and hydrogen. In acetogenesis, acetogen converts the remaining volatile fatty acids and alcohol into methanogenic susbtrate while methanogen convert this product to methane in methanogensis stage. The different temperature ranges for aanaerobic digestions are listed below.

* Psychrophilic condition ranges from 13-17 °C (landfill/ swamp)
* Mesophilic condition ranges form 33-38 °C (anaerobic digester)
* Thermophilic condition ranges from 55-60 °C (gothermally heated ecosystem)

 (Malik, Gunjal, Khasulla, & Gunjal, 2019)

Figure 4: Anaerobic digestion process flow

1. Purification of raw biogas

The raw biogas has to be upgraded and H2S has to be scrubbed and removed which ranges from (0.1-0.3)% and after removing the H2S content the same gas is then passed through the CO2 scrubbers and the CO2 is removed and the high pure methane is formed. Purification of biogas to BioCNG helps to eliminate the impurities like H2O, N2, O2, H2S, NH3, and CO2 are eliminated from biogas. Thus, fermentable organic wastes are converted into clean, cheap and versatile fuel. Generally, physical absorption, chemical absorption, pressurized water adsorption, membrane permeation and biological filtration methods are used to purify such impurities. The calorific value of BioCNG is about 52 MJ/kg which is higher than the calorific value of petrol (48 MJ/kg) and diesel (44.8 MJ/kg) (Pavan, Muthamma, Nakaya, & Harish, 2021)

Table 4: Biogas equivalence to other fuel (Pavan, Muthamma, Nakaya, & Harish, 2021)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.N. | Fuel | Kerosene | Firewood | Cow dung | Charcoal | Butane | Coal gas | Electricity |
| 1 | 1 m3 biogas | 0.620 L | 5.56 Kg | 12.296 Kg | 1.458 Kg | 0.433 Kg | 1.177 m3 | 5.56 kWh |

1. Compression of enriched bio methane

The raw biogas formed inside the digester contains around 60 % of methane (CH4), 40% of carbon dioxide (CO2) and 0.20 % hydrogen sulphide (H2S) which is processed further for upgradation. The raw biogas pass through H2S scrubber for removing H2S. Thus, CO2 and CH4 blown towards activated carbon tower for removal of CO2 partially (30-40). Then, after partial removal of CO2, the gas further is blown (290-310 m3 per hour) towards 16 bar compressor. The 16 bar compressor compresses the gas at 15.85 bar pressure and pushed towards the membrane for separation of CO2 and CH4. Further, compressed CH4  (which should be more than 90% ) is depressurized from 15.85 bar to 0.25 millibar with the help of pressure regulating system (PRS) (Awafo & Amenorfe, 2021).

1. Storage of BioCNG

The BioCNG cylinders are placed on trucks and brought to a fuelling station or at the customer site, where it can be distributed or use for their application in cooking, heating and transportation. The cascades are made up of high strength stainless steel which can handle pressure upto 250 bars. The cascade of capacity 500 kg, 400 kg and 100 kg are used for transportation at costumer end (Pavan, Muthamma, Nakaya, & Harish, 2021)

1. Fertilization

Each day, a portion of the treated feedstock becomes slurry and shall be pumped into a nearby storage lagoon. This slurry shall be separated into solid and liquid manure. Solid manure will be dried on land and excess liquid component shall be sprayed on the rows of solid component before further drying and bagging. The slurry that comes out from digestion can acts as a high quality organic fertilizer to enhance agriculture productivity. This help to minimize use of chemical fertilizer and provide an eco-friendly way of maintaining productivity and soil health (Shah, et al., 2017)

## Parameters affecting bio gasification

1. Substrate temperature

Anaerobic digestion process occurs between 30°C-70°C. The process of biogasification slows down considerably below 30oC, the optimum begin at 35-38oC which is known as the mysophyllic range. Above this temperature the process slows between 40-45oC and then increase to a peak between 55-60oC known as the thermophilic range (Baccioli, et al., 2019)

Table 5: Substrate temperature for different bacteria (Baccioli, et al., 2019)

|  |  |  |
| --- | --- | --- |
| S.N. | Digestion | Optimum |
| 1 | Psycrophilic | 15-18 °C |
| 2 | Mesophilic | 28-33 °C |
| 3 | Thermophilic | 50-60 °C |

1. Retention time

The retention time is the theoretical average time interval that the substrate would remain in the digester. It is calculated as the volume of the digester devided by the volume of the slurry included per day. The gas generation rate will drop when the retention time is decreased and the method may come up short due to a condition called wash out where the microbes culture decrease to the point that they are now not compelling. Depending on the digester temperature, for a cow-dung plant, retention time varies from 40 to 60 days. (Awafo & Amenorfe, 2021).

1. pH level

The pH is a major determining parameter in biogasification. The bacteria live best in slightly alkaline condition. Once the method of digestion starts under anaerobic conditions, the pH will ordinarily take on a esteem of between 7 and 8.5 (Ilyas, 2006).

Table 6: pH level for biogas production (Ilyas, 2006)

|  |  |  |
| --- | --- | --- |
| pH | 7-7.2 | Optimum |
| pH | < 6.2 | Acidic |
| pH | > 7.6 | Basic |

1. C/N ratio

Carbon and nitrogen are the most supplements for anaerobic bacteria. Whereas carbon supplies vitality, nitrogen is required for building up the cell structure. Bio degradable carbon to accessible nitrogen portion of 25:1 has been found to be perfect for biogas generation. The bacteria utilize carbon 25 to 30 times as quickly as nitrogen, hence the ideal C/N ratio is 25 to 30:1 (Shah, et al., 2017). The C/N ratio of some of the commonly used material is present in table below.

Table 7: C/N ratio for different organic waste (Shah, et al., 2017)

|  |  |  |
| --- | --- | --- |
| S. N. | Raw Material | C/N Ratio |
| 1 | Human excreta | 8 |
| 2 | Chicken waste | 10 |
| 3 | Pig dung | 18 |
| 4 | Cow/Buffalo dung | 24 |
| 5 | Water hyacinth | 25 |
| 6 | Straw(maize) | 60 |

1. Pressure

In the anaerobic digestion process, pressure is the blending control which impacts the gas circulation for technologies lacking mixing facilities. An increase in the partial CO2 pressure decreases the pH value lowering the non-ionized ammonia concentration. On the other hand, a decrease in the partial CO2 pressure increases the pH level lowering the non-ionized hydrogen sulphide concentration (Ilyas, 2006).

## Current status of BioCNG in Nepal

Few organizations are converting organic waste to BioCNG for cooking purpose as substitution of LPG. Since last 4 years (2017-2021), BioCNG were introduced in Nepal for institutional cooking and electrification purposes. Envipower Energy and Fertilizers Pvt. Ltd. is Nepal’s first commercial BioCNG plant located at Sukrauli, Nawalparasi with capacity of producing 2 tonnes of BioCNG and 25 tonnes of organic fertilizer daily which requires 30-40 tonnes of organic waste. The company has invested NPR 22 corer to establish the plant. On the other hand, Gandaki Urja Pvt. Ltd., is second and Nepal’s largest commercial scale BioCNG plant. The feeding capacity of the plant is 45 TPD of organic waste to generate 100 cylinders of gas and 2 tonnes of fertilizer daily. In late 2019, it received NPR 5 corer from IFC-backed Business Oxygen (BO2), Nepal’s first private equity fund and the country’s only climate-focused fund. Khilung Kalika Agro Farm Pvt. Ltd. located at Syanja is the only plant with agro farm and biogas plant to generate BioCNG for electricity production of 350 kW for internal electricity consumption. Companies sell these gas cylinders to school and hospitals canteens, restaurants and banquets for cooking purposes. World Bank in collaboration with Alternative Energy Promotion Center, GoN funds the 40% of the total investment on machinery and equipments for the development of the plant. Till now, 15 companies have received the license for producing BioCNG from organic waste and additional 17 are in process of getting the license.

# CHAPTER THREE: RESEARCH METHODOLOGY

This chapter addresses the selection of different procedures and tools used to collect and evaluate data that is based on constructivist approach and case study type research strategy. Detail methodology used in this research which includes research design, research strategy, research process, tool creation, data collection procedures and data analysis techniques are explained herein.

## Research framework

The research study sought to analyze the technical and financial study of energy generation through anaerobic digestion of waste organic matter at BioCNG plant of Gandaki Urja Pvt. Ltd, Pokhara. This research will audit past works, highlight the variation in biogas production, discover the key players of cost contributors and give an overview of the whole processes towards scaling-up and commercialization when performing a techno-financial analysis. The technical objectives include maximizing biogas productivity and process stabilization. The financial targets are to play down the generation cost and maximize the financial benefits. Financial analysis is based on the process design which includes the cost assessments and investment analysis. The research design sought to address the following research queries regarding the BioCNG technology and business:

1. Study site and time
2. Feedstock evaluation
3. Anaerobic digestion parameters
4. Raw biogas purification process
5. Enrich biomethane compression technology
6. BioCNG storage facility
7. Organic fertilizer production system
8. BioCNG vs petroleum comparison
9. Environmental performance
10. Future prospects of BioCNG applications
11. BioCNG production cost
12. Commercialization of BioCNG
13. Cost-benefit analysis

**Value chain**

**-**Waste Collection

-Pretreatment

-Anaerobic digestion

-Biogas upgrading

-Fertilization

**Process specifics**

**-**Digesters, agitators, pumps

-Nutrient addition

-Water mixing

-Heating digesters

**Cost assessment**

**-**Capital cost (fixed, working)

-Operating cost (raw materials, utilities, labor, and repairs)

**Investment analysis**

-Project lifetime

-Discount rate

-Payback period

-Net present value

-IRR

Technology framework and progress

Market study and sensitive analysis

Dynamic connection and optimization

Figure 5: Research framework for BioCNG production and commercialization

## Methodology for research

The research methodology starts with the problem identification. The problem of the BioCNG industry is indentified by over-viewing its production and distribution through interviews and literature reviews. Literature review is done by going through report and published journal from internet. Primary data of monthly production and sales of both products (BioCNG & fertilizer) over the months, and its supply chain is studied through participation. Questionnaires are forwarded to the managers and experts from industries and feedback are collected. Lastly, conclusion are drawn and the management committee are suggested for making the selection decision in improving its supply chain.



Figure 6: Methodology of research

## Study site

Since 2018, two large commercial BioCNG plants are in operation. Envipower Energy and Fertilizer Pvt. Ltd is the first of its kind in Nepal which is situated at Nawalparasi. Likewise, Gandaki Urja is the second and largest commercial BioCNG plant in Nepal in operation. It is located in Majhuwa, Pokhara Metropolitan City. The data collection for the research was done in Gandaki Urja plant. The company is managed by a group of young entrepreneurs and energy experts who focuses more in research and innovation in clean tech business. This made an easy environment to select the site for the research. Also the distance to travel from Kathmandu is also short in comparison to the other one.

## Data collection

The data and information presented in this study were gathered from a variety of sources that incorporate literature review of the journal articles, previously conducted technical assessment and a wide array economic foundation on financial analysis. For the case study, a well-arranged questionnaire was used to gather the information on waste sources, energy generation and market. In the study also used was an array of existing studies on similar projects.

The plant study was conducted on the month of April 2021. The analysis of the feedstock available, gas and fertilizer production and gas up-gradation study was performed for a week.



Figure 7: Research architect process diagram

1. Primary data

Under primary source, relevant information has been collected by questionnaire survey through interviews, observations, document reviews and visual data analysis. Information was gathered from journals, research studies, library database and SCADA in the study site. Data on the status of biogas usage, energy sources previously used; amount of money used for energy sources, the experience of using biogas, i.e. the opportunities and barriers for the adoption of large-scale biodigester for energy production and the benefits.

1. Secondary data

Under secondary source, relevant information has been collected through reviewing records and publications of BioCNG in Nepal through website, journals, magazines and research papers.

## Data analysis

Once the information was captured in survey arrange, Microsoft excel spread sheet was utilized to capture the data from each survey. The information was organized in a way that made it conceivable to examine information on a question-by-question premise and recognize the errors. A comparative analysis was used to interpret the data collected. This was done through comparison with experience and studies from other countries on biogas technology. The past failures and current achievements of biogas technology, in rural areas and status of the technology, the availability of feedstock’s for the digesters, and state of knowledge of operating and maintaining digesters were compared to reach a conclusion. The analysis of current consumption pathways with prices of organic residues as well as the current situation was determined for realization of proper and beneficial running of BioCNG facilities.

# CHAPTER FOUR: RESULTS AND DISCUSSIONS

## Technical analysis

### Selection of place and time for the study

Till date only two commercial BioCNG plant are in operation: Gandaki Urja Pvt. Ltd. and Envipower Energy and Fertilizer Pvt. Ltd. situated at Pokhara and Nawalparasi respectively. As Gandaki Urja has the largest and high-tech BioCNG plant in the country with less travelling distance from Kathmandu, the site was selected for the research. The study was conducted during the month of April and the geographical parameters measured during study period are listed below:

Table 8: Geographical parameters measured during study period

|  |  |  |
| --- | --- | --- |
| S.N. | Parameters | Value |
| 1 | Latitude | 28°05’49’’N |
| 2 | Longitude | 84°05’14’’E |
| 3 | Altitude | 588m AMSL |
| 4 | Average Ambient Temperature | 24.3°C |

### Evaluation of the feedstock available in the system

The amount of gas produced in biogas digester also depends upon the quality and quantity of feedstock added to it daily provided the plant is technically all right. Cow dung, chicken litter and pig manure were the major feedstock used. The sources for these feedstock and their average availability quantity with lab test results from 1-30 April 2021 is tabled below:

Table 9: Sources and average availability quantity of different feedstock

|  |  |  |  |
| --- | --- | --- | --- |
| S.N. | Source | Feedstock | Quantity (TPD) |
| 1 | Adhikari Gai Farm | Cow Dung | 1.40 |
| 2 | Kahu Deurali Farm | Cow Dung | 1.08 |
| 3 | Hemja Gai Farm | Cow Dung | 0.38 |
| 4 | Janaki Agro,Chauthe | Cow Dung | 1.18 |
| 5 | Palungtar Poultry | Chicken Litter | 9.60 |
| 6 | Bhattrai Poultry, Bagmara | Chicken Litter | 3.81 |
| 7 | Bhattrai Poultry, Chinnedada | Chicken Litter | 0.13 |
| 8 | Pig Farm  | Pig Manure | 0.48 |
|   |   |  Total | 18.06 |

Table 10: Lab test results of feedstock

|  |  |  |
| --- | --- | --- |
| S.N. | Parameter | Value |
| 1 | pH | 6.43 |
| 2 | TS % | 20 |
| 3 | VS % | 70 |

From the table, palungtar poultry provides 9.60 TPD of chicken litter which is the highest quantity of feedstock available for the plant during the study period. Among the available feedstock, chicken litter was the highest with average 13.54 TPD, followed by 4.04 TPD cow dung and 0.48 TPD pig manure. Some other sources of feedstock includes Naghdhunga Cow Farm, Jay Buddha Cow Farm, Khilung Kalika Poultry Farm and Lumbini Sugar Industry and Pokhara vegetable market. Although the total capacity of the digester is 45 TPD of waste, due to the Covid pandemic and lockdown, the demand of the BioCNG has reduced drastically, thus reducing the intake of daily feedstock to around 18 TPD. The lab test results of feedstock was pH 6.43, TS 20% and VS 70%.

### Study of anaerobic digestion parameter

About 18 tons of mixed feedstock were fed daily during the study period in the preparation tank to produce 1014 m3 of raw biogas and 456 Kg of BioCNG. The feedstock were collected from the farms through trucks and tractor. In the preparation tank water was supplied in equal ratio with the feedstock and mixed homogeneously with the help of agitator. It dissolves feeder materials clearly with water. Adding water to feedstock regulate the ammonium content and other constituents of the slurry suspension .The materials collected in the preparation tank is in slurry form and sent to digesters through pipeline by the use of feed pump on batch wise basis with interval of 10 min every hour. Two chambered Continuous Stirred Tank Reactor (CSTR) anaerobic digesters: primary and secondary with capacity 2500 m3 and 1700 m3 respectively is used for raw biogas production within the mesophilic temperature range between 35°C to 38°C. There are three agitators inside the digester which runs for 5 minute on interval of every 30 minutes for 24 hours. The agitators can be repositioned by using the lifting and swiveling devices in order to improve the homogeneous nature of the mixture. The digester also includes a heating system in order to compensate for heat loss and warm up the substrates during winter season. The studied technical parameters of feeding and digestion zones taken from SCADA are tabled below:

Table 11: Feeding zone technical parameter

|  |  |  |
| --- | --- | --- |
| S.N. | Parameter | Value |
| 1 | Preparation Tank Level | 500 mmH2O |
| 2 | Feed Pump Flow Meter | 19.87 m3/hr |
| 3 | Feed Pump Temperature | 53.46 °C |
| 4 | Feed Pump Speed | 1450 rpm |
| 5 | BMAX Pressure | 0.20 bar |
| 6 | BMAX Speed | 1450 rpm |
| 7 | Walking Floor Speed | 1450 rpm |

Table 12: Digestion zone technical parameter

|  |  |  |
| --- | --- | --- |
| S.N. | Particular | Type |
| 1 | Type of digestion | Anaerobic |
| 2 | Mode of digestion | Wet |
| 3 | Type of stage | Multi stage |
| 4 | No. of digester | 2 |
| 5 | Type of membrane | Double |
| 6 | Type of load | Continuous |
| 7 | Capacity | Primary: 2,700 m3 Slurry, 800m3GasSecondary: 1,300 m3 Slurry and Gas |
| 8 | Digester slurry level | 1250mm H20 |
| 9 | Digester bottom temperature | 26.68°C |
| 10 | Digester middle temperature | 27.09°C |
| 11 | Digester top temperature | 26.85°C |
| 12 | Digester air pressure | 4.75mm H20 |
| 13 | Digester gas pressure | 6.64mm H20 |
| 14 | Decanter Feed Pump Speed | 1450 rpm  |

Table 13: BioCNG production

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S.N. | Feedstock | Quantity (TPD) | Biogas (m3) | BioCNG (Kg) |
| 1 | Chicken litter | 13.54 | 812.4 | 365.58 |
| 2 | Cow dung | 4.04 | 181.8 | 81.81 |
| 3 | Pig manure | 0.48 | 19.2 | 8.64 |
|   | Total |   | 1013.4 | 456.03 |

Also, for the full capacity of 45 TPD of organic waste, plant generates 2500 m3 of raw biogas and 1125 Kg of BioCNG. This was calculated using the AEPC standard value for biogas production from different feedstock.

### Study of the biogas upgrading and compression technology

The raw biogas formed inside the digester contains around 60 % of methane (CH4), 40% of carbon dioxide (CO2) and 0.20 % hydrogen sulphide (H2S) which is processed further for upgradation. The raw biogas pass through H2S scrubber for removing H2S. It uses chemical process where in fills are supplied with sodium hydroxide (NaOH). In the scrubbing process, NaOH reacts with H2S dissolved in aqueous solution to form sodium bisulfide (NaHS) and sodium sulfide (Na2S). Thus, CO2 and CH4 blown towards activated carbon tower for removal of CO2 partially (30-40%). Carbon tower contains activated carbon filter of 650 - 700 kg. Then, after partial removal of CO2, the gas further is blown (290-310 m3 per hour) towards 16 bar compressor. 16 bar compressor is based on oil injected screw press technology. The 16 bar compressor compresses the gas at 15.85 bar pressure and pushed towards the membrane for separation of CO2 and CH4. The membrane technology have pores which separates CO2 and CH4. Further, compressed CH4 (which should be more than 90%) is depressurized from 15.85 bar to 0.25 millibar with the help of pressure regulating system (PRS).

Table 14: Up-gradation zone technical parameter

|  |  |  |
| --- | --- | --- |
| S.N. | Parameter | Value |
| 1 | After gas blower 1 pressure  | 115.90 mBAR |
| 2 | Gas blower 1 speed  | 887.43 rpm |
| 3 | Gas blower 2 speed | 887.43 rpm |
| 4 | After carbon gas flow | 70.95 m3/hr |
| 5 | After carbon gas pressure | 200.28 mBar |
| 6 | Chiller temperature | 29.09oC |
| 7 | After 16 bar pressure | 11.88 Bar |
| 8 | Membrane temperature | 25.160C |

Table 15: Gas analysis after up-gradation

|  |  |
| --- | --- |
| Gas analysis before purification | Gas analysis after purification |
| CH4% | CO2% | H2S ppm | CH4% | CO2% | H2S ppm |
| 59 | 39 | 1289 | 94 | 4 | 15 |

The upgraded CH4 is processed for high compression at pressure of 200 bar by booster compressor in high pressure cylinders. The cylinders are each with a volume of 45L, 65L and 75L which have a capacity of 6 Kg, 11 Kg and 12 Kg each at 150 bars.

Table 16:16 bar compression zone technical parameter

|  |  |  |
| --- | --- | --- |
| S.N. | Parameter | Value |
| 1 | 16 bar inlet pressure  | 201.39 mBAR |
| 2 | 16 bar discharge pressure  | 12.73 bar |
| 3 | 16 bar oil separator pressure | 11.58 bar |
| 4 | 16 bar oil temperature | 92.04°C |
| 5 | 16 bar speed | 59.98 rpm |

### Study of production of organic fertilizer

In case of fertilizer, the slurry after the residual tank cannot be thrown away as that can be used as a very effective fertilizers in the agricultural fields. The overflowed digestate slurry comes to residual tank which is then pumped out by the help of pump to decanter (de-watering) unit. Decanter is placed about 10m height and the feed product is pumped into the decanter centrifuge through inlet. The decanter works on principle of centrifugal forces (1450 rpm) which separates liquid from solid (70-75% moisture) digestate. Feed goes into a horizontal bowl, which rotates. The bowl is composed of a cylindrical part and a conical part. The separation takes place in the cylindrical part of the bowl. The fast rotation generates the centrifugal force and the solid particle with higher density are collected and are allowed to drop down through nozzle type shape and separated liquid are collected on the other side. Liquid digestate water contains pH value of 8.1 which is pumped to lagoon pit and recirculated in course of feeding and solid digestate is further converted to organic fertilizer through the method windrow composting process. Generally, it takes 35-40 days to convert solid digestate into organic fertilizer as per Nepal Standard parameter. With 18 TPD of feedstock 1TPD of organic fertilizer was produced while with full capacity of plant, it is assumed to be 2 TPD. Organic fertilizer from biogas plant has proved to be high quality manure rich in humus. It plays an important role in supplying plant nutrients, enhancing the cat-ion exchange capacity, improving soils aggregation, increasing water holding capacity of the soils, stabilizing its humid content, and preventing the leaching of nutrients. The lab test results of different parameters of organic fertilizer obtained as the bio-product of BioCNG is listed below:

Table 17: Lab analysis of organic fertilizer

|  |  |  |
| --- | --- | --- |
| S.N. | Particular | Value |
| 1 | Color | Black-brown |
| 2 | Odor | Odorless |
| 3 | pH | 7.78 |
| 4 | Moisture | 30% |
| 5 | Nitrogen | 1.5% |
| 6 | Phosphorous | 0.5% |
| 7 | Potassium | 1.5% |
| 8 | C:N | 7.09:1 |
| 9 | Arsenic | 2.52 mg/Kg |
| 10 | Cadmium | 5.12 mg/Kg |
| 11 | Chromium | 17.15 mg/Kg |
| 12 | Lead | 53.51 mg/Kg |
| 13 | Mercury | ND |
| 14 | Salmonella | ND |
| 15 | Shigella | ND |

### Energy balance of the plant

Different types of machines were used for complete production and storage of BioCNG and organic fertilizer. The list of machines with energy consumption is tabled below:

Table 18: Machine used with energy consumed

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S.N | Machines | Usages | Power (kW) | Time (h) | Energy (kWh) |
| 1 | Balloon Blower 1 | Gas | 0.37 | 15 | 5.55 |
| 2 | Balloon Blower 2 | Gas | 0.37 | 3 | 1.11 |
| 3 | Condensate Pit Pump | Gas | 0.75 | 3 | 2.25 |
| 4 | Lagoon Pump | Fertilizer | 3.2 | 4 | 12.8 |
| 5 | Chemical Dosing Pump | Gas | 0.75 | 10 | 7.5 |
| 6 | Cooling Fan | Gas | 0.75 | 10 | 7.5 |
| 7 | Booster Compressor | Gas | 30 | 10 | 300 |
| 8 | B-Max Pit Pump | Gas | 1.5 | 1 | 1.5 |
| 9 | Decanter Pit Pump | Fertilizer | 1.5 | 4 | 6 |
| 10 | Chopper | Gas | 5.5 | 2 | 11 |
| 11 | Compressor | Gas | 61.8 | 10 | 618 |
| 12 | Biogas Blower 1 | Gas | 3.7 | 10 | 37 |
| 13 | Scrubber Tower Pump | Gas | 2 | 10 | 20 |
| 14 | Feed Pump | Gas | 4 | 4 | 16 |
| 15 | Decanter Feed Pump | Fertilizer | 2.5 | 2 | 5 |
| 16 | Mixing Agitator | Gas | 9 | 5 | 45 |
| 17 | Residue Agitator | Fertilizer | 9 | 7.3 | 65.7 |
| 18 | Digester Agitator 1 | Gas | 18.5 | 7.3 | 135.05 |
| 19 | Digester Agitator2 | Gas | 18.5 | 7.3 | 135.05 |
| 20 | Digester Agitator 3 | Gas | 18.5 | 7.3 | 135.05 |
| 21 | B-Max Pump | Gas | 18.5 | 4 | 74 |
| 22 | Decanter | Fertilizer | 20 | 2 | 40 |
| 23 | Macerator | Gas | 20 | 2 | 40 |
| 24 | Local Loads | Fertilizer | 10 | 14 | 140 |
| 25 | Cooling Fan | Gas | 3.7 | 10 | 37 |
| 26 | Boiler | Gas | 2.5 |   | 0 |
| 27 | Biogas Flaring | Gas | 0.5 | 2 | 1 |
| 28 | Biogas Blowers 2 | Gas | 3.73 | 10 | 37.3 |
| 29 | Dryer | Fertilizer | 7.5 | 6 | 45 |
| 30 | Chiller | Gas | 3 | 6 | 18 |
| 31 | Shredder | Gas | 15 |  8 | 120 |
| 32 | Turner | Fertilizer | 17 |  5 | 85 |
|   | Total |  |  |  | 2204.36 kWh/day |
|  |  |  |  |  | 8 GJ/day |
|  | Actual consumption |  |  | 60% | 4.8 GJ/day |

(1 GJ=277.77 kWh)

Table 19: Energy generated from produced BioCNG

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S.N. | Capacity | Biogas (m3/day) | BioCNG (Kg/day) | Energy (GJ/day) |
| 1 | 18 TPD | 1014 | 456 | 23.8 |
| 2 | 45 TPD | 2500 | 1125 | 52.3 |

(Calorific value of BioCNG= 52.3 MJ/kg)

From the above table, about 4.8 GJ/day energy is required for the complete production and storage of BioCNG and organic fertilizer which is about 20% of the total energy generated at 18 TPD capacity and about 9% of the full capacity of 45 TPD.

### Fuel substitution

BioCNG has the higher calorific value in compared to LPG, diesel and petrol. At 18 TPD capacity, produced BioCNG can replace 518 Kg, 495 L and 570 L of LPG, diesel and petrol respectively. Similarly, 1152 Kg, 1102 L and 1268 L of LPG, diesel and petrol respectively at 45 TPD capacity.

Table 20: BioCNG substitution with other fuel

|  |
| --- |
| Assumption:Calorific values of given fuel:LPG- 46 MJ/KgDiesel- 48 MJ/KgPetrol- 42 MJ/Kg |
| S.N. | Plant capacity (TPD) | BioCNGProduced(Kg) | LPGSubstitution(Kg) | DieselSubstitution(L) | PetrolSubstitution(L) |
| 1 | 18 | 456 | 518 | 495 | 570 |
| 2 | 45 | 1125 | 1152 | 1102 | 1268 |

### Carbon reduction

From the production and use of BioCNG, LPG has been replaced for cooking purpose. This will reduce around 320 TPY of CO2 emission with 18 TPD capacity and 715 TPY with 45 TPD capacity. Similarly, comparing with diesel and petrol 1900 TPY and 1775 TPY CO2 emission will be reduced at full capacity.

Table 21: Carbon emission reduction

|  |
| --- |
| Assumption:C02 emission from burning given fuel:LPG- 1.7Kg/lPetrol- 2.2 Kg/lDiesel- 2.7 Kg/l |
| S.N. | Plant capacity (TPD) | C02e reduction from LPG(TPY) | C02e reductionFrom Diesel(TPY) | C02e reductionFrom Petrol(TPY) |
| 1 | 18 | 320 | 488 | 458 |
| 2 | 45 | 715 | 1086 | 1018 |

## Financial analysis

### Period of analysis

The project will be in operation for a period of 20 years excluding construction period of 12 months. Although the project is for 20 years the loan tenor being for 10 years hence, the financial analysis period has been taken as 10 years.

### Debt equity ratio

Waste to energy projects requires huge capital investment and developer alone cannot invest such amount. Therefore, loan has been arranged from financial institution. The debt equity ratio is 70:30. The estimated subsidy component is adjusted in the estimated loan amount, bringing the total loan portion to about 32.5% of total investment.

### Discount rate

The discount rate on debt investment is the interest rate as agreed during financial closure; however it has been assumed as 12% p.a. for the financial analysis.

### Loan repayment period

The loan repayment period has been estimated as 10 years from the first year of generation.

### Exchange rate

The currency exchange rate used in the economic analysis is IRS1= 1.6015 NRs. as of 2017 and assumed that no escalation during the construction period.

### Taxes, duties and VAT

The financial cost includes custom duties and VAT which have been estimated at 5% and 13% respectively wherein applicable. These taxes apply in respective amount. Apart from these, a corporate tax of 25% will be applicable on the income generation from the sales revenue.

### Bonus to employees

The project will distribute bonus to its employees as per the regulation of the country and it is assumed that the amount will at the rate of 10% of the profit before tax.

### Royalty

A royalty of 1% on the gross sale has been proposed to be given to the municipality on a yearly basis.

### Insurance premium

It is assumed that the insurance premium to be paid for this project will be 0.5% of all fixed assets excluding land annually project financial cost.

### Depreciation

The project value will be depreciated annually at the rate of 5% based on the concession period of 20 years. Miscellaneous fixed assets will be depreciated annually at the rate of 25% as per regulations.

### Capital expenditure

The initial capital cost required for the project has been segregated in different categories as shown in table below:

Table 22: Capital expenditure

|  |  |  |
| --- | --- | --- |
| S.N. | Fixed Asset Investment | Amounts In '000 NPR |
| 1 | Land & Development | 2,250 |
| 2 | Segregation- Preparation Area  | 1,944 |
| 3 | Steel Stack Structure With Chequered Plate | 3,064 |
| 4 | Reactor Stack Foundation | 1,345 |
| 5 | Rcc Saddle Structure For Reactor In Ground Floor | 897 |
| 6 | Underground Tank | 1,614 |
| 7 | Office Buildings | 640 |
| 9 | Electrical | 95 |
| 10 | Sanitary Works | 190 |
| 11 | Contingency | 285 |
| 12 | Machinery | 233,178 |
| 13 | Office Equipment & Furniture Fixture | 500 |
| 14 | License, Registration, Feasibility Study | 2,000 |
| 15 | Misc | 500 |
|  | Total Fixed Investment | 248,502 |

### Labor costs

The cost of labor has be estimated for 12 month in the year as shown in the below and the escalation in salary is hiked by 7.5% each year after the second year.

Table 23: Labor cost

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S.N. | Position | Number | Monthly Salary | Total Salary |
| 1 | General Manager | 1 | 38000 | 456,000.00 |
| 3 | Plant Manager | 1 | 36000 | 432,000.00 |
| 4 | Plant Engineer | 1 | 25500 | 306,000.00 |
| 5 | Plant Operator | 2 | 18500 | 444,000.00 |
| 6 | Accounts Staff | 1 | 14000 | 168,000.00 |
| 7 | Marketing Staff | 1 | 14000 | 168,000.00 |
| 8 | Sales Staff | 1 | 14000 | 168,000.00 |
| 9 | Driver | 1 | 13000 | 156,000.00 |
| 10 | Security | 2 | 13000 | 312,000.00 |
| 11 | Helpers | 2 | 10000 | 240,000.00 |
| 12 | Cook | 1 | 10000 | 120,000.00 |
|   | Total | 18 |   | 2,970,000.00 |

### Operation and maintenance cost

Fixed maintenance costs for the project during operation years have been projected at 0.5% of fixed assets invest excluding land and land development and pre-operational costs. Variable maintenance costs for the project during operation years have been projected at 0.5% of fixed assets invest excluding land and land development and pre-operational costs. An annual escalated at 7.5% (inflation rate) after the second year of operation on wards. In addition to this, a lump sum of NRs.0.5 Million cost has been allocated for administration cost which is also escalated similar to operation and maintenance cost. Cost of sales has been calculated as per estimated requirement which is about NRs. 1.09 Million with an annual escalated at 7.5% (inflation rate) after the second year of operation on wards.

Table 24: Annual operation and maintenance cost

|  |  |  |  |
| --- | --- | --- | --- |
| S.N | Annual Operating Cost (Capacity At 100%) |   | Amounts In '000 Npr |
| 1 | Depreciation Building And Civil Works @  | 5% |  336.00  |
| 2 | Depreciation Machinery & Equipment @  | 5% |  7,772.67  |
| 3 | Depreciation Furniture/Fixtures @  | 25% |  83.33  |
| 4 | Insurance Percentage Of Fixed Assets Excluding Land | 0.50% |  812.67  |
| 5 | Administrative Expenses | Ls |  333.33  |
| 6 | Repair & Maintenance (%f Tangible Assets) | 0.50% |  812.67  |
| 8 | Utilities Percentage Of Total Sales | 0.40% |  150.00  |
| 9 | Amortization  | 20% |  333.33  |
| 10 | Interest On Long Term Loan  |   |  6,454.67  |
| 11 | Labor |   |  2,970.00  |
| 13 | Cost Of Sales & Departmental Expenses |   |  728.00  |
| 14 | Mkt. & Sales Promotion & Csr |   |  374.00  |
| 17 | Electricity Units /Day | 668 |  1,625.33  |
| 19 | Repair And Maintenance Percentage Of Tangible Assets | 0.15% |  487.33  |
| 20 | Commission Percent Of Bottle Sales | 1.25% |  486.67  |
| 22 | Interest on Loan |   |  3,184.67  |
| 23 | Tax |   |  1,926.00  |
| 24 | Bonus to Employees @5% of PBT |   |  7,437.33  |
| 25 | Total Annual Cost Of Operation |   | 36,311 |

### Price list

The price of the different sizes of BioCNG cylinders and organic fertilizer bags are liste below.

Table 25: Price list of BioCNG and organic fertilizer

|  |  |  |  |
| --- | --- | --- | --- |
| S.N. | Particular | Weight (Kg) | Price (Rs) |
| 1 | 45L BioCNG | 6 | 610 |
| 2 | 65L BioCNG | 11 | 1118 |
| 3 | 75L BioCNG | 12 | 1220 |
| 4 | Fertilizer | 3 | 150 |
| 5 | Fertilizer | 25 | 600 |
| 6 | Fertilizer | 40 | 950 |

### Sales revenue

The sales revenue has been projected base on the following assumption; total plant capacity of 45 MT yields 2500 m3 of raw biogas, after refined we get about 1125 Kg of BioCNG daily. The gas shall be sold at NRs. 101/kg i.e. NRs. 1218 per 12kg cylinder. A total 4000 cylinder shall be in circulation. Organic fertilizer is projected to sell at NRs. 24/Kg for 40 and 50 Kg pack while Nrs. 50/Kg for 3Kg pack. The total yearly sale revenue projected is NRs. 58.993 Million at 100% capacity.

Table 26: Annual sales revenue

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S.N. | Sales (Kg) | Qty/Day | Price/Kg | Amount | Annual Sales |
| 1 | BioCNG | 1125 | 101 | 113,625.00 |   |
| 2 | Fertilizer | 2000 | 24 | 48,000.00 |   |
|   | Total |   |   | 161,625.00 |  58,993,125.00  |

### Annual profit statement

From the table, the annual net profit of the company is calculated to be Rs. 22,682,125.00.

Table 27: Annual profit

|  |  |  |  |
| --- | --- | --- | --- |
| S.N. | Sales revenue | Total Cost | Net Profit |
| 1. | 58,993,125.00 | 36,311,000.00 | 22,682,125.00 |

### Payback period

Taking the 40% government subsidy in capital expenditure, with annual profit of Rs. 22,682,125.00, the payback period will be in 7th yr of selling of products.

Table 28: Payback period with subsidy

|  |  |  |  |
| --- | --- | --- | --- |
| S.N. | Capital Expenditure | Annual Net Profit | Years |
| 1. | 149,100,600.00 | 22,682,125.00 | 6.5 |

Taking without 40% government subsidy in capital expenditure, with annual profit of Rs. 22,682,125.00, the payback period will be in 11th yr of selling of products.

Table 29: Payback period without subsidy

|  |  |  |  |
| --- | --- | --- | --- |
| S.N. | Capital Expenditure | Annual Net Profit | Years |
| 1. | 248,501,000.00 | 22,682,125.00 | 11 |

### Financial and investment assessment

The total financial requirements of the project along with its financing sources have been shown in table below:

Table 30: Financial and investment assessment

|  |  |  |
| --- | --- | --- |
| S.N. | Investment Scenario | Amount In 000’s NPR |
| 1 | Total Investment Required | Nrs. 248,502 |
| 2 | Equity | Nrs. 79,520.64 |
| 3 | Subsidy | Nrs. 99,400.8 |
| 4 | Debt | Nrs. 69,580.56 |
| 5 | Debt/Equity/Subsidy Ratio | 32%/28%/40% |
| 6 | Pay Back Period with Subsidy | 6.5 yrs |
| 7 | Pay Back Period without Subsidy | 11 yrs |

# CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

## Conclusion

This study presents the techno financial analysis of BioCNG plant as an alternative fuel through anaerobic digestion of organic waste. A series of methods were employed in order to achieve the objectives of the research. Different technical and financial parameters were analysed for the study of the plant. From the field study of Gandaki Urja, following conclusion has been made.

1. The total waste processing capacity of the plant is 45 tons leading to the generation of 2500 m3 of raw biogas, 1125 Kg of BioCNG and 2000 Kg of organic fertilizer per day.
2. Due to the covid pandemic and lockdown, the demand of gas and fertilizer were reduced drastically. This minimized the feedstock in the plant to 18 TPD leading to generation of 1014 m3 of raw biogas, 456 Kg of BioCNG and 1000 Kg of organic fertilizer per day.
3. From the table, palungtar poultry provides 9.60 TPD of chicken litter which is the highest quantity of feedstock available for the plant during the study period. Among the available feedstock, chicken litter was the highest with average 13.54 TPD, followed by 4.04 TPD cow dung and 0.48 TPD pig manure.
4. With 18 TPD of feedstock 1TPD of organic fertilizer was produced while with full capacity of plant, it is assumed to be 2 TPD. Organic fertilizer from biogas plant has proved to be high quality manure rich in humus with pH 7.78, moisture 30%, nitrogen 1.5%, phosphorous 0.5% and potassium 1.5%.
5. About 4.8 GJ/day energy is required for the complete production and storage of BioCNG and organic fertilizer which is about 20% of the total energy generated at 18 TPD capacity and about 9% of the full capacity of 45 TPD.
6. BioCNG has the higher calorific value in compared to LPG, diesel and petrol. At 18 TPD capacity, produced BioCNG can replace 518 Kg, 495 L and 570 L of LPG, diesel and petrol respectively. Similarly, 1152 Kg, 1102 L and 1268 L of LPG, diesel and petrol respectively at 45 TPD capacity.
7. From the production and use of BioCNG, LPG has been replaced for cooking purpose. This will reduce around 320 TPY of CO2 emission with 18 TPD capacity and 715 TPY with 45 TPD capacity. Similarly, comparing with diesel and petrol 1086 TPY and 1018 TPY CO2 emission will be reduced at full capacity.
8. The financial feasibility of the project was also assessed taking 10 years as the analysis period. The total yearly sale revenue projected is NRs. 58.993 Million at 100% capacity. The annual net profit of the company is calculated to be Rs. 22,682,125.00. Taking the 40% government subsidy in capital expenditure, with annual profit of Rs. 22,682,125.00, the payback period will be in 7th yr of selling of products. Taking without 40% government subsidy in capital expenditure, with annual profit of Rs. 22,682,125.00, the payback period will be in 11th yr of selling of products. The debt/equity/subsidy ration was found to be 32%/28%/40%.

## Recommendation

Based on the research, following are the major recommendations:

1. The study need to be conducted in different BioCNG plants at different time interval (0-1, 1-5, and 5-10 yrs) with variability in feedstock for more accurate results.
2. Energy audit need to be done in regular interval for minimizing the energy losses from the plant.
3. Study on heat losses from the digester due to temperature variation and filtration parameters of raw biogas is needed with more accurate methods and resources.
4. Laboratory study in the reduction of TS and VS needs to done.

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# APPENDIX I: LETTER OF REQUEST



# APPENDIX II: LETTER OF RECOMMENDATION



# APPENDIX III: QUESTIONNAIRE

1. CONTACT INFORMATION
2. Company Name:
3. Company Address:
4. Plant Address:
5. E-­‐mail address:
6. Telephone Number:
7. PROJECT INFORMATION
8. What types of biomass and/or waste are processed in the digester?
9. What are the quantities per major category of biomass and/or waste that are currently processed in the digester? (Biomass A, x ton/day, waste By ton/day).
10. What are the sources of biomass and /or waste?
11. Are there industries (animal husbandry, slaughterhouses, etc.) that could regularly supply these waste and by-­‐products to the plant? Yes/no. If Yes: Which waste and by-­‐products and how many (ton/year)?
12. Are there agro-food companies in the vicinity of the plant that could regularly supply bio wastes? Answer Yes/no. If Yes: Which bio-­‐wastes and how many (ton/day)?
13. What are the modes of waste collection?
14. What is the overall plant capacity? (ton/day)
15. Are the incoming biomass and/or waste subject to any pretreatments? (Eg. Mechanical, thermal, chemical, biological, etc.)
16. Which process is your plant following and what is the number of digesters? (Eg. dry, semi-­‐ dry, humid etc. two primary and one secondary).

11. Design parameters of digester.

* 1. Temperature:
	2. Pressure:
	3. pH:
	4. C/N ratio:
1. What is the capacity of primary and secondary digester?
2. Gas purification technology.
3. Gas compression technology.
4. Gas bottling technology.
5. What is the average biogas content (%)?
6. What is the calorific value of biogas produced?
7. What is the average refined biogas content (%)?
8. What is the calorific value of BioCNG produced?
9. What is the hydraulic retention time?
10. What is the operation time of the plant?
11. What is the end use of digestate?
12. Is the plant equipped with a composting unit? Answer Yes/no. If Yes: What is the amount of digestate sent to the composting unit (ton/day)?
13. Technology used in fertilizer production?
14. What is the amount of compost fertilizer produced?
15. What is the composition of fertilizer?
16. Do you have any plant related-­‐problems with the neighbors (odour, traffic, noise, etc.)?
17. Name of consulting and construction company for BioCNG plant.
18. Project financials.
19. MARKET INFORMATION
20. What are the different sizes and prices of BioCNG cylinders?
21. What is the total nos. of customer of BioCNG?
22. Who are the customers of BioCNG?
23. What are the different sizes and prices of fertilizer bag?

# APPENDIX IV: PLAGIARISM

