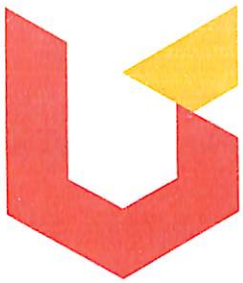

UPES

Benefits of Developing Biogas Power Plant to Solve Energy Deficit and Promote Economic Growth in India

By,

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A DISSERTATION REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

MBA. POWER MANAGEMENT

OF

CENTRE FOR CONTINUING EDUCATION

UNIVERSITY OF PETROLEUM & ENERGY STUDIES, DEHRADUN

Acknowledgement

This is to acknowledge with thanks the help, guidance, and support that I have received during the Dissertation.

First and foremost, I would dedicate my greatest appreciation to my Spiritual Guide and Father, Sri Siva Shankar Baba for bestowing me His blessings, courage, and motivation to complete this dissertation successfully. I would also like to thank my beloved wife Roshni for her love, care, and encouragement throughout this undertaking.

I have no words to express a deep sense of gratitude to the management of WABIO Technologie GmbH for allowing me to pursue my Dissertation and in particular Dr. Auerbach, for his guidance and support.

I must also thank Mr. Domogalla and Ms. Mielich for their valuable support and advice. I also place on record my appreciation of the support provided by Ms. Samriti Mahajan and other staff of University of Petroleum and Energy Studies (UPES).

Sincerely,

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- Handel mit Getreide, Futter- und Düngemittel
- Verwertung von biogenen Roh- und Abfallstoffen
- Biotechnologische

Gowree Sankaran
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23.01.2020

Declaration Letter

Dear Sir or Madam,

This letter is to certify that Mr. Gowree Sankaran, a student of MBA. Power Management, SAP ID: 500056723 of UPES have successfully completed this dissertation report on "Benefits of Developing Biogas Power Plant to Solve Energy Deficit and Promote Economic Growth in India" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analyzed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfillment for the award of degree of MBA.

Thanking you.

Sincerely,

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Abstract

The goal of this dissertation is to bring to the limelight the importance and benefits of developing biogas power plants to tackle numerous problems involving energy deficits in most rural areas as well as promoting economic growth of India. Considering various ecological problems due to global warming and pollutions, significant measures must be taken immediately and implemented to ensure the existing habitation is suitable for future generations. This thesis investigates the current problems caused by fossil fuel power plants such as crude oil, lignite, hard coal, natural gas and explains the advantageous biogas power plants as well as proposes enhanced environmentally friendly methods to generate the same electrical and thermal energy more efficiently through biogas systems. Moreover, this thesis shall also investigate the existing conventional biogas generating plants and suggests selective techniques to upgrade the system for better performances. The methodology of structuring this thesis shall be a combination of qualitative and quantitative approaches. Likewise, the research viewpoints adopt a permutation of pragmatism and subjectivism to prove the concept to be more feasible for modern-day society in various industries which also includes agriculture. To solve the current issues mainly involving power failures and farmer distress in India, this thesis may be a suitable guide to formulate strategies henceforth.

List of Abbreviations

AD	Anaerobic Digestion
CDM	Clean Development Mechanism
CER	Certified Emissions Reduction
CHP	Combined Heat and Power
CSF	Critical Success Factors
CSR	Cooperate Social Responsibilities
COD	Commercial Operation Date
CPP	Coal Power Plant
CH4	Methane
CO2	Carbon Dioxide
DMT	Dry Metric Tonne
EUR	Euro Currency
GHG	Green House Gas
GW	Gigawatts
GWh	Gigawatts Hours
INR	Indian Rupees
IRR	Internal Rate of Return
ITP	Inspection Test Plan
KW	Kilowatts
KWh	Kilowatts Hours
Kg	Kilograms
MSW	Municipal Waste
MWh	Megawatts Hours
MJ	Mega Joules
NH	Northern Hemisphere
NPV	Net Present Value
RFP	Request For Proposal

RFQ	Request For Quotation
R&D	Research and Development
N2O	Nitrous Oxide
O&M	Operation and Maintenance
SBTi	Science Based Targets initiative
USD	United States Dollar
WTE	Waste To Energy

Contents

1. Introduction

1.1. Overview

Based on the Human Development Indices and Indicated which was produced by the United Nations, India ranked 130 in the Human Development Index and was classified as Medium Human Development Nation.

For India to ascend to the Very High Human Development segment, the nation should give more importance to the implementation of renewable energy projects. India can improve its ranking which shall cover the following indicators below as stated in the Sustainable Development Goal:

1) End hunger, achieve food security and improved nutrition and promote sustainable agriculture;
2) Ensure availability and sustainable management of water and sanitation for all;
3) Ensure access to affordable, reliable, sustainable and modern energy for all;
4) Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation;
5) Take urgent action to combat climate change and its impacts;
6) Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss;
7) Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

The above-mentioned standards can be achieved by implementing large scale biogas power plants in future energy-based projects. The question that needs to be addressed is, 'To what scope and extent should biogas power plant be incorporated?' Industrial culture may differ based on the diverse locations as perception towards a particular idea can be easily dismayed without careful consideration. There could be various factors that could contribute to such occurrences such as technological limitations, social norms, and conceptual presumptions. Since the power industry has now started to become very dynamic and innovative, numerous new technologies have been developed and marketed on a large scale. This makes it easy for energy investors to obtain any specific technology they desire.

Apart from the generation of electricity, biogas power plants can be an ideal method of dealing with different kinds of waste materials effectively. Due to the large population and unreliable authorities, India has been struggling to manage domestic and industrial waste efficiently and safely. Biogas systems can convert these waste materials into useful organic fertilizers that can be used or recycled for agriculture purposes.

1.2. Background

As the contemporary world societies are gaining more awareness of the harmful effects of global warming caused by the pollutions released to the atmosphere by various industries, there are several mechanisms introduced to promote the development of renewable energy projects to generate clean energy. However, the level of participation to stimulate renewable energy growth has not met the expected results due to the influences of global politics, government regulations, environmental forces, financial markets, customer preferences as well as lack of understanding on the possible economic potentials these projects are able to

generate. Certain visionary Indian companies have begun to realize the adverse effects of global warming and have taken essential measures to collaborate with international companies to encourage such undertakings. For example, India's leading alloy steel manufacturer Mahindra Group joint ventured with the two Japanese companies Sanyo and Mitsui & Co to form Mahindra Sanyo as a combined effort to reduce emissions from heavy industry.

'The business became the first company from an emerging economy to set a science-based target on climate change and have this approved by the Science Based Targets initiative (SBTi). This officially recognizes that the goal is in line with meeting the Paris Agreement's ambition of keeping global warming well below 2°C above pre-industrial levels. The company set its target following a pledge from the chairman of the Mahindra Group, Anand Mahindra, who committed that all his companies would do this at the World Economic Forum in Davos in 2018. This was alongside a wider challenge he set out to businesses around the world, calling for 500 companies globally to commit to science-based targets in advance of the 2018 Global Climate Action Summit in San Francisco.'

Along with it, the United Nations Framework Convention on Climate Change has introduced a Clean Development Mechanism (CDM) to clean development projects in developing countries.

The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and sold, and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol.

These mechanisms were designed to encourage developing countries such as India to meet the emission reduction commitments without acutely impacting the country's economy.

'The CDM is the main source of income for the UNFCCC Adaptation Fund, which was established to finance adaptation projects and programs in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change. The Adaptation Fund is financed by a 2% levy on CERs issued by the CDM.'

Therefore, interested energy investors can obtain such benefits thus reduce the payback period and breakeven point to make their investment more profitable from the incentives gained.

1.3. Purpose of the Study

The goal of this thesis is to inspire energy investors and government bodies to be meticulously aware of the importance of developing Biogas Power Plant projects and its positive contribution financially, economically, and also environmentally. In line with the above-mentioned objective, this work shall also incorporate the methods of efficiently developing a biogas system as per the latest technology.

1.4. Research Hypothesis

The main objective of the thesis is to explain the importance and potentials of Biogas Power Plant systems and to provide the energy investors with strategic mechanisms and

development plans to remain competitive or better than other conventional systems such as fossil fuels incinerator boilers. The thesis investigates how incinerator boilers exploit the environment and how biogas systems are able to provide the same desired results without harming the atmosphere. The result of the thesis includes both strategic suggestions and opportunities for enhancement. By reviewing the outcomes, one can validate the degree of applicability to invent Biogas Power Plant Systems in India based on the research objectives of the thesis stated below:

a) The first research hypothesis relates to the environmental advantages gained:
   - Biogas power plant emits lesser greenhouse gas into the atmosphere compared to fossil fuel power plants thereby makes it more environmental friendly

a) The second research hypothesis relates to the financial and economic advantages gained:
   - Biogas power plants can generate greater revenue whereby the construction costs are lesser and the payback period is faster compared to fossil fuel power plants

b) The third research hypothesis relates to the community and social advantages gained:
   - Biogas power plants are easier to implement in small and large scale thereby makes it more preferable in rural areas to promote agriculture, waste management, and job opportunities

2. Literature Review

Essential terms, concepts, models, facts, and technologies concerning relevant Biogas Power Plant system related subjects are introduced hereunder. This literature review shall deal with different aspects of management including what Biogas Generation System initiatives are, the responsibilities of energy investors and project managers and the integration of Biogas Generation System initiatives into business objectives and divisions. However, the dynamic nature of the global business environment, uncertainties in political situations, rapid technological inventions, financial market instability, and budget constraints creates an unpredictable scenario for energy investors to achieve the desired outcome. Besides that, project management has become more unpredictable than previously foreseen in almost all industries, which makes it challenging and intricate to ensure the anticipated success of a particular project.

The information in the Literature Review is utilized based on the broad and narrow considered evaluations, as well as during the creation and formulation of suggestions and opportunities for improvement are included.

The first theme discusses the notion of Biogas by explaining what the concept of Biogas Power Plant represents, the motivations behind its development and its evolution from the first generation to date. The remaining three themes discuss the possibilities of biogas generation system to create an impact in the energy market, energy investor's responses towards integrating Biogas Power Plants in the power industries and different induced theories required for accomplishing integration of Biogas Power Plants projects.

2.1. Review Area Broad

2.1.1. Importance of Biogas Generation Systems

Recently, a joint efforts of a group of biogas experts from Denmark, Germany, Austria, and Greece, as part of the BiG>East project, (EIE/07/214/SI2.467620), with an overall aim of promoting the development of biogas from anaerobic digestion in Eastern Europe has mentioned that one of the main environmental problems of today's society is the continuously increasing production of organic wastes. In many countries, sustainable waste management, as well as waste prevention and reduction, have become major political priorities, representing an important share of the common efforts to reduce pollution and greenhouse gas emissions and to mitigate global climate changes, Teodorita Al Sead and Dominik Rutz, (2008). He discusses many of the contemporary motives behind Biogas generation systems, particularly in relation to organic waste disposal. This provides the reader with a wider understanding of Biogas Generation Systems and how it has progressed since it was initially limited to a certain particular industry such as agriculture or domestic and now it deals with any waste which has organic contents. Teodorita Al Sead and Dominik Rutz, (2008) mentions that uncontrolled waste dumping is no longer acceptable today and even controlled landfill disposal and incineration of organic wastes are not considered optimal practices, as environmental standards hereof are increasingly stricter and energy recovery and recycling of nutrients and organic matter is aimed. Here, the author mentioned that biogas generation systems are not only considered better than fossil fuel power plants, instead, but it is also even more preferred than incineration systems as burning the organic materials in the furnace causes higher emissions and waste materials are not safe for disposal until the appropriate treatments are given.

The development of a nation should be decentralized and proportionate to ensure all sides of the community are taken into account. The most basic necessity to meet the requirement is to provide an uninterrupted electricity supply to promote social welfare as well as industrialization. Through industrialization, job opportunities will be ample at various locations and they shall also establish appropriate infrastructures to support the business. Hence the population crisis at metropolitan cities can be evaded and the overall growth of the nation is secured. Dr. Sunil Kumar (2012) stated that in developing countries, due to the imbalance of demand and supply of energy, mainly in rural areas, choosing a source that fulfills the requirements has become essential, and they can use waste as other raw materials. Biogas, which is mainly generated from organic waste, is useful for them. Thus, the implementation of biogas production caters to environmental and socio-economic benefits for society as a whole. Application of the internal value chain improves local economic capabilities, maintains jobs in rural areas and increases regional purchasing power. It develops living standards and contributes to economic and social development.

2.2. Review Area Narrow

2.2.1. Fundamentals of Biogas Generation Systems

Biogas is produced in a biological process whereby a combustible mixture of gas is generated which consists mainly of methane (CH_4) and carbon dioxide (CO_2). In an anaerobic atmosphere (absence of oxygen), organic matter derived from the fuel materials is broken down to form a gas mixture known as biogas. M. Kaltschmitt, F. Scholwin (2010) explained that the organic matter is converted almost entirely to biogas by a range of different microorganisms. Energy (heat) and new biomass are also generated. The resulting gas mixture consists primarily of methane (50-75 vol. %) and carbon dioxide (25-50 vol. %).

Biogas also contains small quantities of hydrogen, hydrogen sulphide, ammonia, and other trace gases. The process by which biogas is formed can be divided into many steps (see Fig.2.1). The individual stages of decomposition (degradation) must be coordinated and harmonized with each other in the best way possible to ensure that the process as a whole runs smoothly.

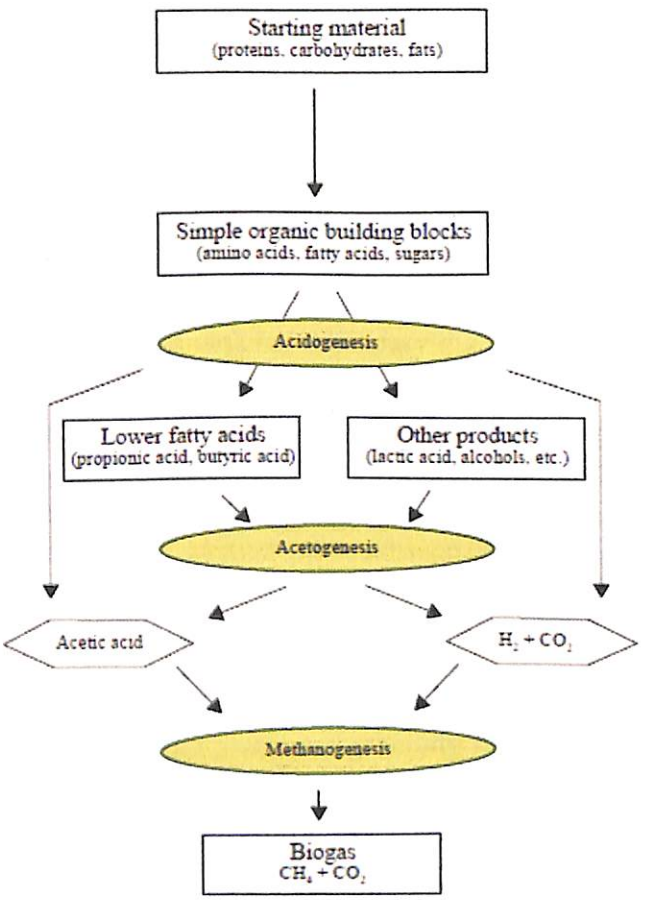

Figure 2.1: Schematic representation of anaerobic decomposition

The materials are initially prepared with an appropriate amount of organic matter and moisture content to suit the capacity of the plant before feeding into the digesters or fermenters. The organic material or fuel undergoes a mixing and hydrolysis process to ensure the organic compounds are suitably degraded before feeding it into the fermenters. M. Kaltschmitt, F. Scholwin, (2010) stated that during the first stage, hydrolysis, the complex compounds of the starting material (such as carbohydrates, proteins, and fats) are broken down into simpler organic compounds (e.g. amino acids, sugars, and fatty acids). The hydrolytic bacteria involved in this stage release enzymes that decompose the material by biochemical means. Additionally, Teodorita Al Sead and Dominik Rutz, (2008) mentioned that the main products of this process are biogas and digestate. Biogas is a combustible gas, consisting primarily of methane and carbon dioxide. Digestate is the decomposed substrate, resulted from the production of biogas.

Peter Jacob Jørgensen (2009) explained that different biomasses are moreover mixed in the reception tanks to ensure the biomass fed to the reactor is homogenous. Slurry reception tanks typically have sufficient storage capacity for seven days and are often covered concrete tanks.

The reactor tank is a completely enclosed and insulated steel tank or a concrete tank covered by an airtight seal. The tank can be fitted with heating coils that warm the digesting biomass, or the heat supply can be external via a heat exchange system. At the top of the tank, there is an outlet for the biogas produced. During gas condensation, when cooled, most of this water will condense out and can then be pumped back to the secondary digester. During the gas purification, this can be done in a biological process, where the ability of sulphur bacteria to degrade hydrogen sulphide to pure sulphur or sulphuric acid is utilized. This sulphur in an aqueous solution is pumped to the secondary storage tank and therefore recycled to the field and crops. The purpose of the storage tank (or secondary digester) is to act as a buffer tank before the digested biomass can be transported away to be finally stored in the farmer's own storage tank or applied as fertiliser directly on farmland. During gas storage, in order to even out the gas production, most plants also have a gas store with capacities ranging from two to 24 hours of production. Biogas takes up a lot of space and it is rarely worth having a large storage capacity. In gas transmission, purified gas is subsequently pumped from 5-10 km in a gas transmission pipe to a local combined heat and power plant, where the biogas may replace natural gas.

The above-mentioned process flow by Peter Jacob Jørgensen (2009) is a conventional biogas production system where most existing plants are generally functioned. However, there are more advanced systems where different types of fermentation techniques are operated such as hydraulic fermenters, a combination of mesophilic and thermophilic culture fermenters, digestate biofiltration recycling inhibitor stations and desulphurization columns. The typical process flow of a biogas power plant is shown in figure 2.2.

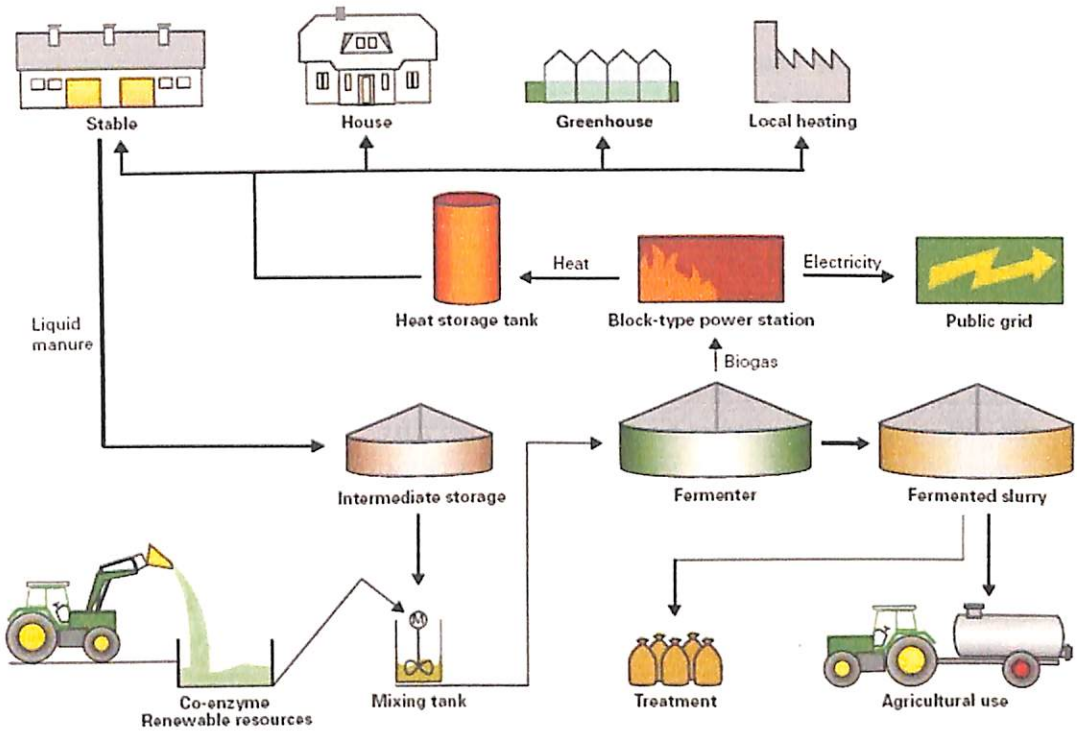

Figure 2.2: Biogas Production Typical Process Flow

2.2.2. Advantages of Biogas Generation Systems

Biogas production is a reliable renewable energy source. Teodorita Al Sead (2008) mentioned that unlike fossil fuels, biogas from AD is permanently renewable, as it is produced on biomass, which is actually living storage of solar energy through photosynthesis. Biogas from AD will not only improve the energy balance of a country but also make an important contribution to the preservation of the natural resources and to environmental protection. This essentially brings to notice that fossil fuel is a non-renewable source of energy where the existing reserved are at present being consumed much more than the formation of new ones.

Moreover, biogas production can reduce greenhouse gas emissions and mitigation of global warming. Dominik Rutz (2008) stated that the carbon cycle of biogas is thus closed within a very short time (between one and several years). Biogas production by AD reduces also emissions of methane (CH_4) and nitrous oxide (N_2O) from storage and utilisation of untreated animal manure as fertiliser. Even though biogas production also releases carbon dioxide (CO_2), it will be consumed back to the plant for the photosynthesis process. Therefore, this makes biogas production carbon neutral by achieving a null net value of CO_2 emissions by offsetting the carbon emission with removal. For example, the generated carbon emissions from a biogas plant that utilizes waste materials from an agriculture industry will be recycled back to the plantation through the consumption of new or existing plantations during the photosynthesis process.

Biogas production reduces dependency on imported fossil fuels. Dominik Rutz (2008) mentioned that developing and implementing renewable energy systems such as biogas from AD, based on national and regional biomass resources, will increase the security of national energy supply and diminish dependency on imported fuels. Based on a report from Government Of India, Ministry of Power Central Electricity Authority, New Delhi, it states that the All India Installed Capacity of fossil fuel power plants which includes coal, gas, and diesel amounts up to 222692.59 MW. Besides that, the report mentioned that in the year 2015 to 2016, India has consumed a total of 545.9 million tonnes of coal, for power generation. In Indian Petroleum and Natural Gas Statistics, for the year 2012 to 2013, it mentioned that during the year 2013-14 the import of crude oil was 189.238 MMT valued at Rs.8,64,875 crore as against 184.795 MMT production in 2012-13 valued at Rs. 7,84,652. An increase of about 2.40% in quantity terms and 10.22% in value terms has been observed during the year 2013-14 over 2012-13. During 2013-14, 13.032 MMT of LNG valued at Rs. 53,307 crores, was imported, which marked a decrease of 0.79 % in quantity and a 27.74% increase in value terms. Since, India's reserves for coal, crude oil, LNG and diesel are limited and do not suffice to cater to the requirements for the entire country, it is highly dependent on importing these products which irrefutably reflects the high cost to withstand. India has a greater chance to improve its economy, country funds reserves and GDP by focussing more on the renewable energy sector since its fuel requirements are not dependable on another country's resources thereby reducing foreign import levels.

Biogas power plants help to reduce and manage waste in an efficient manner. Teodorita Al Sead (2008) mentioned that biogas production is an excellent way to comply with increasingly restrictive national and European regulations in this area and to utilise organic wastes for energy production, followed by recycling of the digested substrate as fertiliser. AD can also contribute to reducing the volume of waste and costs for waste disposal. A biogas power plant system is the most preferable method to deal with waste products due to its ability to handle wet materials with high moisture content and transform it into valuable organic fertilizers. This method is not possible in incineration systems as it would require high energy and additional processes to dry the fuel before feeding it into the boiler furnace.

Additionally, biogas production encourages job creation. Dominik Rutz (2008) stated that the development of a national biogas sector contributes to the establishment of new enterprises, some with a significant economic potential increase the income in rural areas and creates new jobs.

The consumption of biogas is flexible and efficient at the end-user. Dominik Rutz (2008) stated that one of the simplest applications of biogas is the direct use for cooking and lighting, but in many countries, biogas is used nowadays for combined heat and power generation (CHP) or it is upgraded and fed into natural gas grids, used as vehicle fuel or in fuel cells.

Another significant factor to consider biogas production is low water input requirements. Teodorita Al Sead (2008) mentioned that one of them is that the AD process needs the lowest amount of process water. This is an important aspect related to the expected future water

shortages in many regions of the world. Relatively, fossil fuel or incineration power plants that function through the boiler system require a perennial source of water coupled with a water treatment system to operate the plant safely and efficiently. This requirement also demands the need for additional space to create water storage tanks or ponds, cooling towers and water purification stations. Such sophisticated requirements are not needed for a biogas power plant.

Last but not least, biogas production is very beneficial to farmers. Teodorita Al Sead (2008) stated that the production of feedstock in combination with the operation of biogas plants makes biogas technologies economically attractive for farmers and provides them with additional income. The farmers get also a new and important social function as energy providers and waste treatment operators. Digestate is an excellent fertiliser. The digested substrate, usually named digestate, is a valuable soil fertiliser, rich in nitrogen, phosphorus, potassium, and micronutrients, which can be applied to soils. Dominik Rutz (2008) mentioned that biogas production is a closed nutrient cycle. The methane (CH_4) is used for energy production and the carbon dioxide (CO_2) is released to the atmosphere and re-uptaken by vegetation during photosynthesis. Some carbon compounds remain in the digestate, improving the carbon content of soils when digestate is applied as fertiliser. This shall aid the farmers to grow healthier crops. Biogas production has wide flexibility to use different types of feedstock. Teodorita Al Sead (2008) specified that various types of feedstock can be used for the production of biogas: animal manure and slurries, crop residues, organic wastes from dairy production, food industries, and agroindustries, wastewater sludge, organic fraction of municipal solid wastes, organic wastes from households and from catering business as well as energy crops. Biogas production also reduces odors and flies. Teodorita Al Sead (2008) mentioned that AD reduces these odors by up to 80%. Digestate is almost odorless and the remaining ammonia odors disappear shortly after application as fertiliser. Connectively it ensures veterinary safety as well. Depending on the type of feedstock involved, sanitation can be provided by the AD process itself, through a minimum guaranteed retention time of the substrate inside the digester, at thermophilic temperature, or it can be done in a separate process step, by pasteurization or by pressure sterilisation.

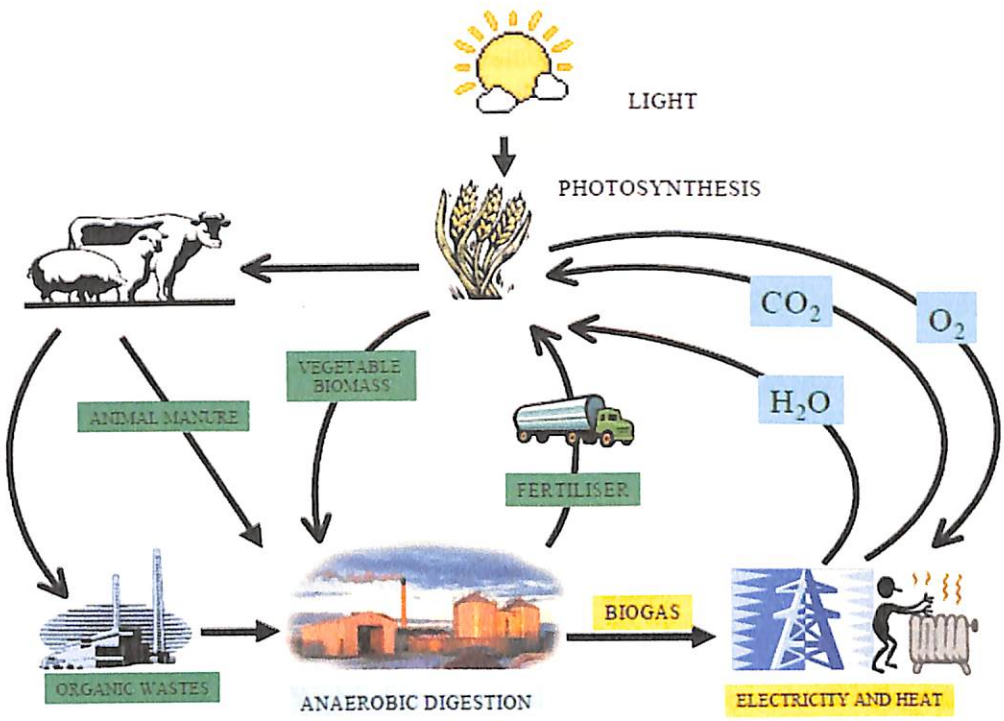

Figure 2.2: The sustainable cycle of biogas from AD

2.3. Factors Critical to Success the Study

Based on the researches of the literature sources and theoretical insights, it can be determined that there is a very close link between the type and scope of projects and respective Critical Success Factors (CSF). To classify the CSF specifically for this particular type of project, it requires imposing limits on the range of possible factors and measures of CSF by conducting an empirical study. However, the practice of utilizing CSFs into business modes is not a new field of work. CSFs concepts and approaches are still very powerful and are applicable to many of the challenges today.

The statement released by CIB 1997 mentioned that there are several factors that determine the success of a project. First of all, the project should have clear and commonly agreed objectives. All the objectives should be carefully thought and consideration. The provision of essential information at each stage of the project is necessary. Apart from that, the project should have a flexible approach that balances the requirements for quality against the concern to freeze requirements to control cost and meet deadlines. Last but not least, the project should have trusting relationships in order to succeed.

There are seven factors to the successful implementation can be identified from the University of York's experience (Blyth and Worthington, 2001):

1) A template for consistently well integrated projects is very important;

2) A transparent framework should be established to determine the expectations, procedures, and performance measures against which evaluation and improvements can be made;
3) Clarification of roles goes parallel with empowered respondents who are able to articulate needs clearly within the long-term strategic framework;
4) Manageable buildings that can absorb changes should be implemented;
5) Consistently monitor and provide feedback by bringing in quality improvements loop to provide better outcome;
6) To make continuous review of the test assumptions and frequently re-examines the hypotheses made. The focus is to provide robust and transparent framework to test the project as it progresses;
7) Concentrating on the innovation which could promise great returns on the investments made. Organisations with continuous building programs have the opportunity to reflect on poor performances, repeat those steps which has proven to yield success, and discover new solutions which needs improvements to achieve great returns.

Additionally, the University of York's has mentioned that the successful briefing demands attention to communication and how information is structured and passed through the system. Designers speak a different language to users, yet they must understand the business language of their clients to allow for meaningful communication of needs. Such identification is significant for clear and comprehensive communication of the project scope. (Blyth and Worthington, 2001).

Therefore, the researcher has concluded that there is a total of four critical success factors that are related to this research. However, it is at utmost importance that a corroborated business plan by taking into account the profit and loss forecast as well as analysing the balance sheet is the determining success for any project. Hence, the success factors are as explained below:

2.3.1. Market Objective

The targeted objective of the market is the first independent variable. It is essential to identify the nature of the market in order to develop a relative competitive position versus the actual supply and demand requirements. A detailed analysis has to be conducted to determine the target customers and the market demand should be large enough to allow the introduction of biogas power plant concept without causing any hindrances or disruptions. There has to be a great value placed to ensure the target group fully understands the ecological impacts the world is currently facing due to the fossil fuel industries and the benefits which can be acquired by investing in green projects in terms of individual and environmental gains. Since certain expertise in the field of biogas may not be available in India, it has to be outsourced to foreign companies to provide the know-how concepts. Therefore, there might be chances where the initial capital and development cost for the first few pilot projects to be higher than usual. Nevertheless, the market target group for high value output provide better opportunities and yield greater results. How the target group view the idea of biogas power plant development is a variable condition which has a significant impact on the success of the project to meet its strategic goals.

2.3.2. Raw Materials

Raw materials are the key factor and the single most important operating variable because it consists of the highest contribution to the operating cost. In order for a biogas plant to operate and generate revenue, and a stable and secure feedstock supply is necessary and requires careful evaluation. The cost of the raw material varies by the type, preparation of processing needed before delivering to the power plant, distance and geographical region necessities. It is important to emphasize that the market group that in case the cost of the raw material is higher than expected, it can't be taken into account as a reason to assume low project performance. Therefore, the cost of the raw material is may vary and has a crucial impact on the success of the project.

2.3.3. System Integration

System integration is introduced when a biogas plant is combined with another sustainable industry. Such integration is established in order to provide economic benefits to generate more profits by enhancing the efficiency and minimizing the overall operating cost ideally for both facilities. For example, since India has wide sugar industries in place, along with the co-production of sugar, the production of ethanol from the bagasse has a very high potential for success in this integrated system. Since system integration is intended to yield greater efficiency, it will eventually lead to lower operating costs and also ensure more sustainable use of the raw materials. However, comprehensive research and evidence have to be proven to win the confidence of the market group to invest in such projects.

2.3.4. Project Acumen and Execution

This factor depends on the level of skills and experiences the business team has to ensure the success of the project. Even though all required skills are present, there is no guarantee that the project can be successful because human error and misjudgments are the most critical variable condition which has a substantial effect in order for the project to meet its strategic goals. The project can fail when the management team is not proficient enough even when all other critical success factors are in place or if a management team is capable and experienced, the project can still succeed even if other critical success factors are deficient. A compelling and stable business plan, strategic partners, sufficient revenue to support performance shortfalls and proper management of risks are some of the key points that must be validated while developing a project.

2.4. Summary

The core purpose of the review is to highlight the inevitable fact that fossil fuel is non-renewable energy and India's domestic output remains stagnant. Given that nationwide development is occurring at a brisk pace, energy consumption has to meet its demands as well. To cope with its needs, India's dependence on foreign resources by importing the fuel will grow proportionately if this situation continues to ensue. Such practice is not farsighted to constantly rely on external assets to run the country's operation when ample to useful resources are available to cater to the needs and go hand in hand with the rapid pace progressions.

As stated in the advantages of the biogas production system above, the implementation of this scheme will be very beneficial to India in order to improve the country's economy, culture and environment. Since India is highly dependent on the agriculture industry and aspires to encourage the growth of the sector, a biogas power plant is the most ideal method to support the farmers to expand their production. All kinds of waste are converted into useful organic fertilizers which can be used back to the plantation grounds without purchasing chemical-based fertilizers. Besides that, the agriculture production factories can be established in the plantation area itself since reliable to the constant provision of electricity to run the process is available. This promotes development in rural areas as well as provides various job opportunities.

Since biogas power plant is the most ideal system to convert wet waste materials into energy or electricity, energy investors and/or government bodies can establish a biogas power plant at MSW landfill so that these waste can be efficiently managed with high productivity. The organic waste can be sent to the power plant to generate waste whereas non-organic waste can be recycled. The final digestate product or fertilizers can be converted into extra revenue which can be sold to external parties given that there are various other treatments available to dry, pelletize and pack it suitably. Such techniques shall convert residence areas into smart-cities by making it waste-free, pollution-free and environmentally friendly. Another additional fact to be included here is that biogas power plants are not as noisy as thermal power plants and it does not emit a high amount of heat since most of the fermenters and tanks are insulated. Therefore, a biogas power plant is more suitable to be operated close to a residential area compared to a thermal power plant or any other incineration system.

3. Research Design, Methodology and Plan

3.1. Data Sources

In this dissertation, this area elucidates the types of methodologies adopted to accomplish this research. Likewise, data sources are a critical part where it determines the precise path of an efficacious research project. For this project, data inputs were collected from Wabio Technologie GmbH, Double Nine Engineering Co.,Ltd and Indonesia Plantation Synergy Bhd as a case study. An online survey was conducted based on standard questions designed to gather details on how the development of biogas power plant systems shall solve energy deficit problems as well as promote economic growth in India.

A questionnaire was formulated to collect information regarding the technological implications, economic benefits, and social welfares which biogas production systems are able to deliver for the Indian community and culture in contrast to fossil fuel power plants or incineration systems. The questionnaires contain a set of simple and straight forward questions to prevent deviation and focusses on the relevant area of details obtained. Thus, the details gathered shall set the base to identify the critical success factors.

3.1.1. Sample Definition

To ensure the relevance of the information acquired, it is vital to assess the samples wisely. The samples were evaluated based on several criteria such as:

a) Whether the respondent has been involved in any biogas production development projects within the last 3 years;
b) Whether the respondent has been involved in a commissioning and operation phase of a biogas power plant;
c) Whether the respondent currently works for a biogas power plant development company whereby his position and years of experience in the field should be included;
d) Whether the respondent has a wide range of knowledge and experience on the technical and commercial field and if the respondent has worked in the following departments such as:
    i. Project Management
    ii. Engineering
    iii. Procurement
    iv. Construction
    v. Commissioning and Operation
    vi. Business Development
    vii. Contract Management

3.2. Research Design

This research is aimed to underline the importance and benefits of developing biogas power plant for electricity generation and various other beneficial factors using quantitative statistical method and a qualitative study as well by incorporating the companies such as Wabio Technologie GmbH, Double Nine Engineering Co.,Ltd and Indonesia Plantation Synergy Bhd which are concerns based in Germany, Thailand, and Indonesia which multiple years of experience in the field of power plant and plantation developments. The major source of data which are essential to prove this research as a success derived from the above-mentioned company.

The research concentrates on the process flow of a biogas production plant, its contribution to the environment, the emission levels, its benefits to the society as well as other industries and financial turnover it is able to produce as a whole. The results are compared with the fossil fuel power plants and the differences are highlighted to investigate which system is more preferable and advantageous for the growth of India. Therefore, the research shall assimilate the procedures involved in the project management, engineering, procurement, construction, commissioning, operation, business development, and contract management.

In order to gather the details for this research, an online survey method was used and circulated to the respective respondents. This allows the respondent to decide a suitable time to answer the questionnaire comfortably and provides them a chance to ponder upon their

answers carefully before submitting it. Besides that, as the respondents are based in Germany, Thailand, and Indonesia, the answers to the questionnaires are expected to be more neutral because of the perspective and advice derived from a party unaffected by the political atmospheres, cultural habits, and social norms are mostly unbiased. To maintain the integrity of the data, this research has been structured in such a method.

3.3. Survey Questions

Measurements tools are a vital instrument that is utilized to gather and record essential details throughout the research. There are various ways to implement these methods for example through observation, interviews, or questionnaires. A questionnaire is a collection of written questions which is given putting all necessary variables for the study and can be completed by respondents in attendance, in his absence, directly or indirectly (Cooper and Schindler, 2006).

The measurement tool implemented in this research is the questionnaire method. This technique is applied to gather and record expert opinions from the above-mentioned organizations who are very experienced in the field of power plant developments and biotechnology systems. A large proportion of current psychological literature is based upon data obtained by means of a questionnaire. By many, this is regarded as a reliable, scientific method (Robert H. Gault, 2012). During the process of distributing the questionnaire to the respective respondents, the scope of expertise was selected in various fields in order to obtain and assess the information on the advantages of biogas production systems from different angles.

The questionnaire is divided into three sections which are intended to extract selective information to make the assimilation process more efficient. In the first part of the questionnaire which consists of five questions, it mainly involves several questions to find out about the academic and working experience of the respondent to know exactly in which field, nature of background, and thought patterns which the respective respondent possesses. The second part of the questionnaire which consists of another five questions involves discovering the technical knowledge the respective respondent possesses in the field of biogas production systems as well as other relative power plants. The third part of the questionnaire which consists of the last five questions involves the respective respondent's opinion and idea of which power production system will yield more benefits and is more advantageous for India. The list of distribution to the respondent from each respective field is mentioned in the table below:

No.	Department	No. of Respondents
1	Project Management	3
2	Engineering	4
3	Procurement	2
4	Construction	3
5	Commissioning and Operation	3
6	Business Development	4
7	Contract Management	4
	Total	23

Table 1: Number of respondent's data collected from each respective department

3.3.1. Questionnaire Design

Part 1: Inquiring the respondent's field, nature of background, and thought patterns

1. What is your past working experience?

The above question is intended to discover the kind of knowledge the respondent possesses to determine in which angle the researcher should perceive his answer, either technically or commercially.

2. In which departments have you worked till present?
    - Project Management
    - Engineering
    - Procurement
    - Construction
    - Commissioning and/or operation
    - Business Development
    - Contract Management
    - Others (Please Specify) .....

The question above is to go more into detail to identify the respondent's experience and thought patterns of whether the respondents comprehend technical and commercial terms and nature of work.

3. What is your academic background?

The question above is meant to discover the respondent's detailed knowledge area and main interest to determine possible influencing factors that may persuade the answers.

4. What is your opinion about power generation in terms of renewable and non-renewable?

The question above is intended to identify the respondent's idea and opinion regarding power generation of whether the respondent is an environmentally friendly person or if the respondent only thinks in terms of business and profits through simple terms. This is to further determine the respondent thought patterns.

5. What is your opinion about the power industries and potentials in the Asian market?

This question above is to find out the respondent's knowledge and experience about the Asian region in order to determine the level of importance and attention to be given by his or her answers

Part 2: Inquiring the respondent's technical knowledge in the field of biogas production systems as well as other power plants

6. What is the most suitable method of generating power in terms of electricity for the Indian regions?

The question above is meant to discover the respondent's knowledge, perception, and experience about India

7. Have you been involved in a biogas power plant construction project? If yes, please state the nature of the project and your job scope.

The question above is to find out if the respondent has knowledge and experience in the biogas production sector as well going more in detail to know about the field of experience the respondent has derived from to further determine the thematic analysis in qualitative terms.

8. What kind of problems have you encountered while developing the biogas power plant and how have you solved those problems? Otherwise, other power plants which you had experienced.

The question above is meant to identify the respondent's technical knowledge of the biogas power plant. This shall categorize the respondent as technically well versed, medium experience or at a beginner stage. Otherwise, this answer shall also reveal if the respondent has been involved only in the commercial and business development scope.

9. Do you agree that the biogas power plant is a suitable method to generate electricity in India? Please provide an explanation for your answer.
    - Agree
    - Disagree
    - Neutral

After investigating well the answers derived from the previous questions, the researcher shall be able to accomplish the thematic analysis efficiently. Henceforth, this question shall play a vital role in determining the respondent's opinion in terms of consideration level to be absorbed.

10. What is the most efficient process flow technology you suggest to be implemented in India?

Once the researcher is able to identify the respondent's technical competence in the field of biogas production, the researcher is able to gain valuable insights into the technologies and inventions possible to improve India's power generation capabilities based on the answers derived from the above question.

Part 3: Inquiring the respondent's opinion and idea of which power production system will yield more benefits and is more advantageous for India

11. What is the difference between the process flow you suggested and other conventional systems?

The question above to highlight the difference between the proposed and other conventional systems in order to assimilate the variance in terms of addition or reduction equipment and stations which reflects on the development cost.

12. Please explain the overall plant efficiency as well as energy balance and describe how the proposed system is more effective compared to other conventional systems.

The question above is to further understand the performance of the system proposed in comparison with other conventional plants whereby the researcher is able to realize the amount of revenue the proposed system can generate per annum and determine the payback period, breakeven point, net income, fixed cost, and total cost.

13. To which stage has your proposed biogas system reached its implementation? Please select the categories below:
    - Patented, developed and yielded results
    - Theoretically proven
    - Conceptual Opinion

The question above is intended to identify whether the proposed system of the respondent has been practically implemented, operated and yielded results or if it is only theoretically proven or if it is just a hypothesis imposed.

14. What are the overall benefits of implementing a biogas power plant in India?

The question above is meant to identify what other advantages of biogas power plant implementation does the respondent advises in various other angles such as agriculture, social welfare, corporate social responsibility (CSR), lifestyle improvements, municipal waste management and many more.

15. Do you think India is prepared to make a shift towards investments in the renewable energy sector and mainly biogas power plant projects considering its current market condition, investment preference, social culture, and political stability?

The question above is mainly intended to seek the possibilities of actually imposing such ideas and innovations in India from the viewpoint of the respondent. Since the respondents are from the western continents, these answers are considered to be unbiased, neutral and uninfluenced by any source or sentiments. This question shall provide essential insights to the researcher to understand the likely channels to approach in order to initiate such a project and setbacks that need to overcome.

3.4. Interview Procedures

The questionnaires were mainly conducted and administered through online/email correspondences due to the definition models as defined in the methodology as well as the tight schedules of the respondents during office hours. Email communications allow the respondent to provide answers at ease by giving them the necessary time which allows them to reflect carefully on the responses so that it fully adheres to their ideology. Besides that, there are six key advantages of an online survey as the following below:

1. Online Surveys are Cheaper
2. Online Surveys are Flexible — for the Researcher and Participant
3. Online Surveys are Fast and Accurate

4. Online Surveys are Versatile
5. Respondent Control
6. Larger Sample Sizes are a Possibility

Since the scope of respondents for this survey derives from Germany, Thailand, and Indonesia there is no possibility of unavailability of internet connection to access this questionnaire. Hence, the respondents prefer this type of survey to be conducted since it does not interrupt their schedules for the day.

3.4.1 Questionnaire Design

The key to gathering the vital details significant to this research is to ensure the respondent understands what is required from them. Therefore, the questionnaire formulated is meant to be direct, simple and straight forward whereby it is divided into three sections:

a) Personal details: This section shall consist of the general details to evaluate the respondent's background;

b) Critical Success Factors (CSF) of the project: This part examines and identifies the critical success factors from the answers and feedback the respective respondent has provided;

c) Critical Success Factors (CSF) Rankings: In this section, the respondents shall rank the success factors they have identified using a given scale.

3.5. Data Analysis Procedure

The method of analysing the data obtained for this dissertation is through evaluating the quantitative as well as qualitative results. The difference between both methods is while the quantitative method deals with analysing statistical graphs, the qualitative technique is executed by comparing and segmenting various data resemblances and conflicts.

As the questionnaires method was implemented via an online survey to gather relevant details, the manner of the qualitative interpretation by which this dissertation was performed is thorough thematic analysis. By studying various data that have been gathered, thematic analysis underlines the pattern which is very helpful in assimilating related data obtained from all the transcripts. Moreover, irrespective of an inductive or deductive approach, thematic analysis can be applied.

4. Research Findings and Analysis

Descriptive Statistics

This part shall include an integrated analysis of the results obtained from the quantitative and qualitative data anatomy which will discern the insights of biogas production power plants from the perspective of the respondents and what are their ideas and commitments to make a

significant positive contribution to Indian society. Thus, the following questionnaires were distributed through an online survey in order to address the requirements of the research theme then to gather the answers and conduct thematic analysis to distinguish the thought patterns. Subsequently, the answers are discussed and reach upon a conclusion whereby recommendations are also acquired to reflect on the theme of this research which is to prove that biogas power plant innovation is very suitable to cater the needs of Indian electricity requirements, solve energy deficits as well as promote various economic and social growths for the nation as a whole.

The results of the questionnaires from the online survey shall now be displayed in a quantitative approach as it statistically represents the respective field expert respondent's responses and the researcher shall compare or associate the results from various angles without being judgemental for better understanding. The online survey in which a compilation of 15 questions was answered by experienced personnel and experts in the field of renewable energy from a German multinational corporation. The survey was circulated to the respective respondent via email and a total of 23 feedbacks were collected as described below:

The online survey was conducted into three main themes in order to fulfill the research objectives leading to the main research motive.

4.1. Findings of the Qualitative Research Method

This section shall analyse the answers from respondents by focussing on three main themes of this research and the qualitative findings are strictly in relation to the Indian market and atmosphere. Therefore, the answers from all the respondents have been examined subsequently similar patterns have been discovered.

4.1.1. Research Theme 1

Inquiring the respondent's field, nature of background, and thought patterns

1. What is your past working experience?
2. What is your academic background?
3. What is your opinion about power generation in terms of renewable and non-renewable?
4. What is your opinion about the power industries and potentials in the Asian market?

Most of the respondent's backgrounds are from the field of renewable energy and small portions from them are from technical agricultural field such as fatty acid extraction, factories, mills and the remaining portions were from oil refinery plants. All the respondents have the relevant experience and knowledge required to understand the concept of power generation and the difference between the processes and outputs of a biogas power plant and a fossil fuel or incineration system power plant.

From the thematic analysis conducted, the researcher is able to discern that the entire respondent are in favour of renewable energy concept to be implemented for electricity generation electricity by considering various factors for the future.

Ms. Mielich mentioned that "Although she previously worked as a contract manager in oil and gas firm, the emission requirements were determined and agreed on papers however it is not assured that the same will be obliged when the construction was completed and the plant is to be commissioned. There have been several cases where contractual clauses were later revised and penalties were imposed because the proposed technical design can't meet the project demands. These revisions will inevitably cause more harm to the environment and contribute to greater GHG emissions"

Thus, she strongly suggests implementing renewable energy projects because the technology is proven. According to her, renewable energy power plants are safer and faster to construct compared to fossil fuel power plants.

Apart from that, Mr. Dietrich also agrees the same with Miss Mielich whereby he has stated that "The safety requirement to construct, commission, and operate a fossil fuel power plant is more complicated compared to renewable energy power plants which involve more time for the execution inspection test plan (ITP) procedures. This shall require more time to reach the commercial operation date (COD)"

4.1.2. Research Theme 2

Inquiring the respondent's technical knowledge in the field of biogas production systems as well as other power plants

1. What is the most suitable method of generating power in terms of electricity for the Indian regions?
2. Have you been involved in a biogas power plant construction project? If yes, please state the nature of the project and your job scope.
3. What kind of problems have you encountered while developing the biogas power plant and how have you solved those problems? Otherwise, other power plants which you had experienced.
4. What is the most efficient process flow technology you suggest to be implemented in India?

After analysing the results from the respondent's answers it can be determined that the technical competence varies accordingly. For example, the knowledge and experience the engineers possess differ considerably from the knowledge of the employees from the business development department. The employees from business development mainly focus on meeting the qualification requirements of the tender or Request For Proposal (RFP) or Request For Quotation (RFQ). They will comprehend the modification to qualify for the bid only at the surface level. This is to enable them to convince the investor that the respective company has the competence and experience to meet the requirements they demand.

Dr. Auerbach who is the technical director for Wabio Technologie GmbH states that "After the involvement of almost 30 projects for the establishment of biogas power plants, I have in detailed experience in the commercial as well as the technical field. Both departments play a vital role to bring success in the project whereby the influence of their role varies during the phases of the project. The commercial department plays an important role at the beginning of

a project whereby they will study the tender and biding requirements in detail and correspond with the engineers of whether the respective design can be implemented and the guarantees can be met. Once the engineering and other technical departments confirm, the commercial department shall proceed with bid submission, presentation and so on to win the contract. When the contract is finalized and the payment terms have been decided, then the engineers and corresponding technical departments take over to meet the contractual requirements and ensure the plant's guarantee. Hence, I consider all departments to be an equal functioning level for every project. As a technical director, one should have experience in both fields prior to taking up such responsibilities"

Moreover, planning the engineering phase is very essential once the contract is finalized. For example, Mr. Stollberg has mentioned that "The respective EPC contractor should study and understand the nature of business in India as well as their working culture. Therefore, it will be easier to succeed in the project by making a joint venture or consortium with an Indian company to develop a biogas plant in India. The biogas power plant which relies on agricultural inputs needs close cooperation with farmers to ensure a steady input. So, such agreements can be accomplished by the Indian partner effectively"

It is necessary to make an appropriate investigation to determine the fuel core properties which are to be utilized for the biogas production in India because the nature of the fuel differs based on the particular environment and lifestyle. Certain fuel derived from specific areas may have higher moisture content due to the greater rainfall. Unlike incineration systems, a biogas production plant requires a higher moisture level for fuel preparation during the fermentation stage.

4.1.3. Research Theme 3

Inquiring the respondent's opinion and idea of which power production system will yield more benefits and is more advantageous for India

1. What is the difference between the process flow you suggested and other conventional systems?
2. Please explain the overall plant efficiency as well as energy balance and describe how the proposed system is more effective compared to other conventional systems.
3. What are the overall benefits of implementing a biogas power plant in India?
4. Do you think India is prepared to make a shift towards investments in renewable energy sector and mainly biogas power plant projects considering its current market condition, investment preference, social culture, and political stability?

After acquiring all the answers provided by the respective respondents, the researcher could determine that all the respondents are in favour of developing biogas power plants in India to solve energy deficits problems as well as promote economic growth. Since most part of India weather condition is stable with constant sunlight available throughout the year, there is a great deal of agricultural industry already in place. Besides that, a survey has shown that India has the highest number of vegetarians in the world. Therefore, there shall be a high

amount of organic waste available in municipal waste (MSW). These wastes contain a high source of potential to be converted into biogas and subsequently energy or electricity.

For example, Mr. Fitz who is the CEO of Wabio Technologie GmbH mentioned that "Biogas alone is the most significant method to solve the waste-related and handling problems in India. Considering that India is already suffering from air pollutions due to vehicle emissions, open burning and many more, the conventional MSW incineration system will not be suitable as the combustion stack gas from the boiler will only aggravate and worsen the existing situation. Energy production in the form of biogas from the wet fermentation technique and electricity generation from combined heat and power (CHP) engines is the most efficient and appropriate method for this issue. This is because the exhaust gas from CHP is carbon neutral thereby it will in no way affect the environment"

Apart from that, the implementation of a biogas power plant is very flexible where it could be developed by various capacities depending on the needs. The capacity of the plant can range from filling the gas tank for cooking to 100 MWth or even more. Subject to the requirement of a specific area in prospective of the fuel amount, community welfare and needs, government rules and regulation, political manifestos and many more the biogas plant can be designed to suit its demands.

Dr. Auerbach has mentioned that "There should only be a constant supply of organic fuel for a biogas plant to operate"

Since India has limited coal, oil and gas resources and most of the existing power plants are operated using fossil fuel. Therefore, India relies substantially on foreign imports to replenish the fossil fuel resources in order to sustain continuous operation. It is not practical to imbibe such practice as this hinders the economic growth of the nation due to the heavy dependence on other nations. As explained in point 2.2.2. "Advantages of Biogas Generation Systems", it has mentioned that in the year 2013 to 2017, India has spent around Rs.8,64,875 on crude oil and Rs. 53,307 of LNG imports. Needless to say, the overall consumption of these fossil fuels has definitely amplified as of 2019 since vehicle usage and industrial development have proportionately increased. To meet the current demands, India has to also escalate fossil fuel imports and siphon out more money from its reserves.

Mr. Stephan from as the head of the department for Business Development has stated that "In the present, countries like China have converted most of its vehicles to run with electricity or biogas, bioethanol, biodiesel, bio-CNG fuelled. This is accomplished to decrease its imports on oil and gas and dependence on other nations. Such acts shall increase by the economic growth of the country by generating greater revenue as well as preserve the cleanliness of the environment. India should also move towards the same direction for its future growth and remain as a competing partner in the global market among the top developed nations"

Thus, India already has the required resources, technologies, experts, and financial strength to implement this scheme and yield its benefits. The only pending requisites are initiative and interest.

4.2. Findings of the Quantitative Research Method

The results of the quantitative research were analysed and described based on the questionnaires from each respective research theme. The quantitative research is very important in order to determine the behaviors and opinions of people towards the concept of renewable energy and biogas systems. Additionally, to further validate the analysis and results obtained from the qualitative research this quantitative research serves as an optimal platform to decide on the respondent's choices in reference to this topic. Hence the quantitative research is also performed based on three themes as shown below:

4.2.1. Research Theme

Inquiring the respondent's field, nature of background, and thought patterns

Question: In which departments have you worked till present?

In order to acquire details regarding the scope of the respondent's experience, they were requested to select the department brackets that they belong to. For this particular question, the respondent is allowed to select more than one answer. The majority of the respondents of 43% belong to the project management department followed by 22% of the engineering department. These two department brackets encompass 65% of the total amount of respondents. The next majority number of respondents belongs to the construction department with 12% of respondents followed by the commissioning and operation department which consists of 8% of the total respondents.

This is followed by the business development and contract management department with each consist of 5% of the total respondents. Next represents the procurement department with 3% and finally others with 2% of the total respondents respectively. The greatest advantage that can be derived from the classification of these respondents is that the majority of them are from the project management department. In the usual working culture, the project management department's job scope overlaps into every respective department to drive and coordinate the project forward with the clients, contractors, sub-contractors and furthermore. Hence, the answer obtained from this survey respondent can be evaluated as mostly all-round as all departments have been considered accordingly.

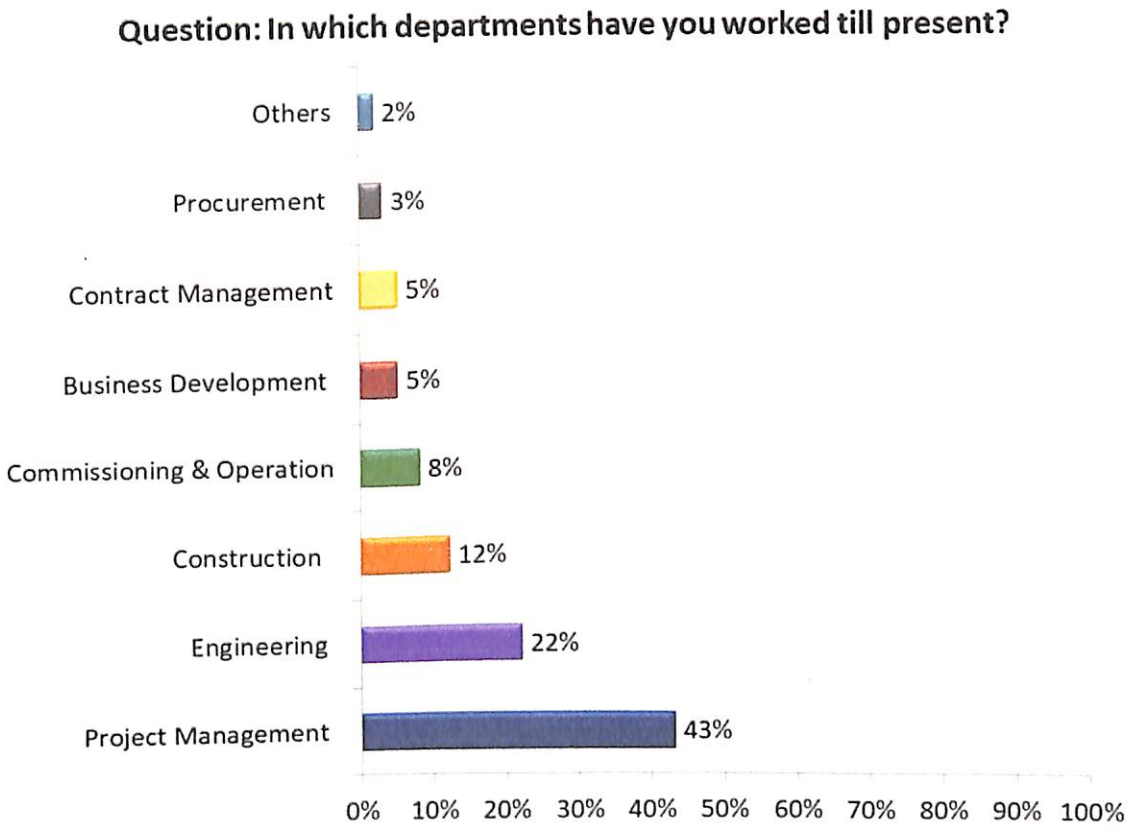

Figure 4.2.1: Scope of the respondent's experience

4.2.2. Research Theme 2

Inquiring the respondent's technical knowledge in the field of biogas production systems as well as other power plants

Question: Do you agree that a biogas power plant is a suitable method to generate electricity in India? Please provide an explanation for your answer.

The above question is a combination of quantitative and qualitative research methods. The researcher is interested in assimilating the respondent's opinions and justification on their choices in the biogas industry perspective. Besides that, this question aims to identify the respondent's behavior on biogas power plants and further signifies the importance of implementing biogas power plants in India. The majority of the respondents agree with the concept of the biogas power plant as a suitable method to generate electricity in India with a total of 95%. Whereas 3% of the respondents were neutral and only 2% disagree with the realization of biogas power plants in India.

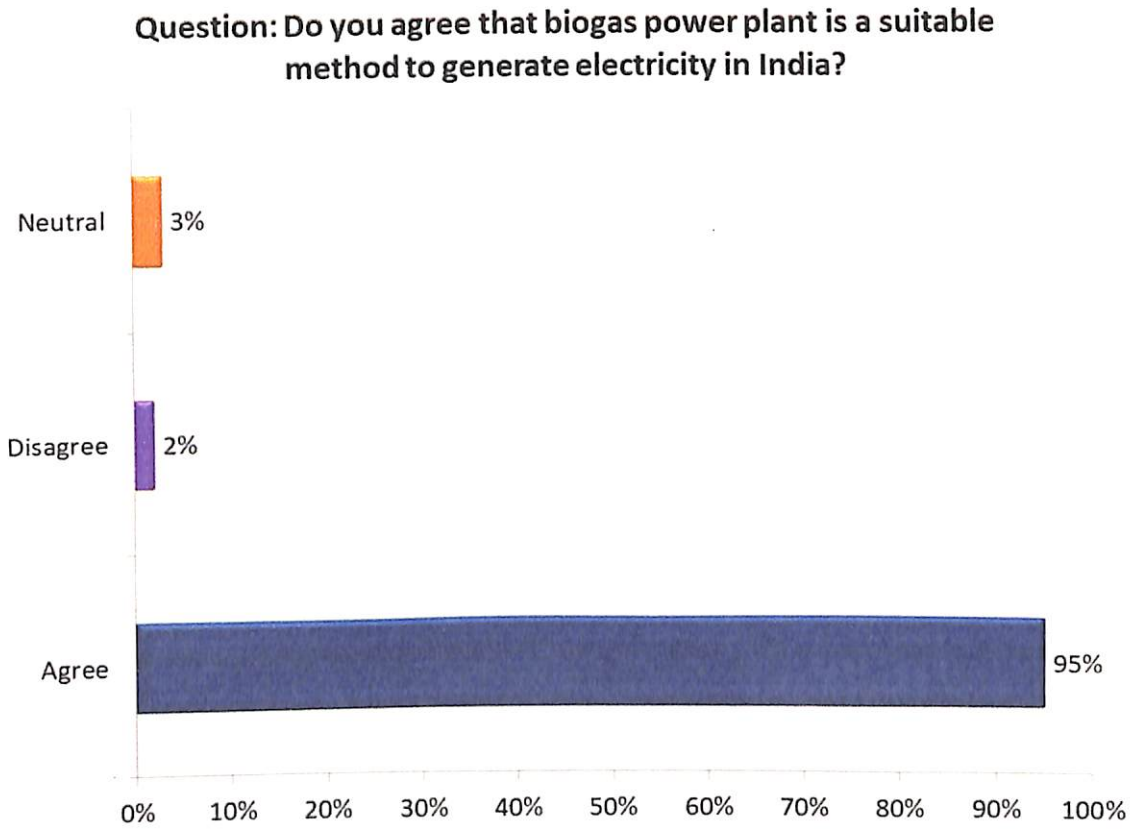

Figure 4.2.2: Respondent's opinion in implementing biogas power plants in India

4.2.3. Research Theme 3

Inquiring the respondent's opinion and idea of which power production system will yield more benefits and is more advantageous for India

Question: Till which stage has your proposed biogas system reached its implementation? Please select the categories below:

The above question addresses the importance given towards a particular answer which the respective respondent proposes of whether it has been patented, tested and yielded results or if it is theoretically proven or if it is just an opinion imposed relatively. This shall enable the researcher to distinguish the weightage to be given on a specific system to be taken to the next stages for possible chances of development. For this question, 50% of the respondent's proposed system has been patented, tested and yielded results. 35% of the respondents proposed system has been theoretically proven and 15% are just opinion imposed.

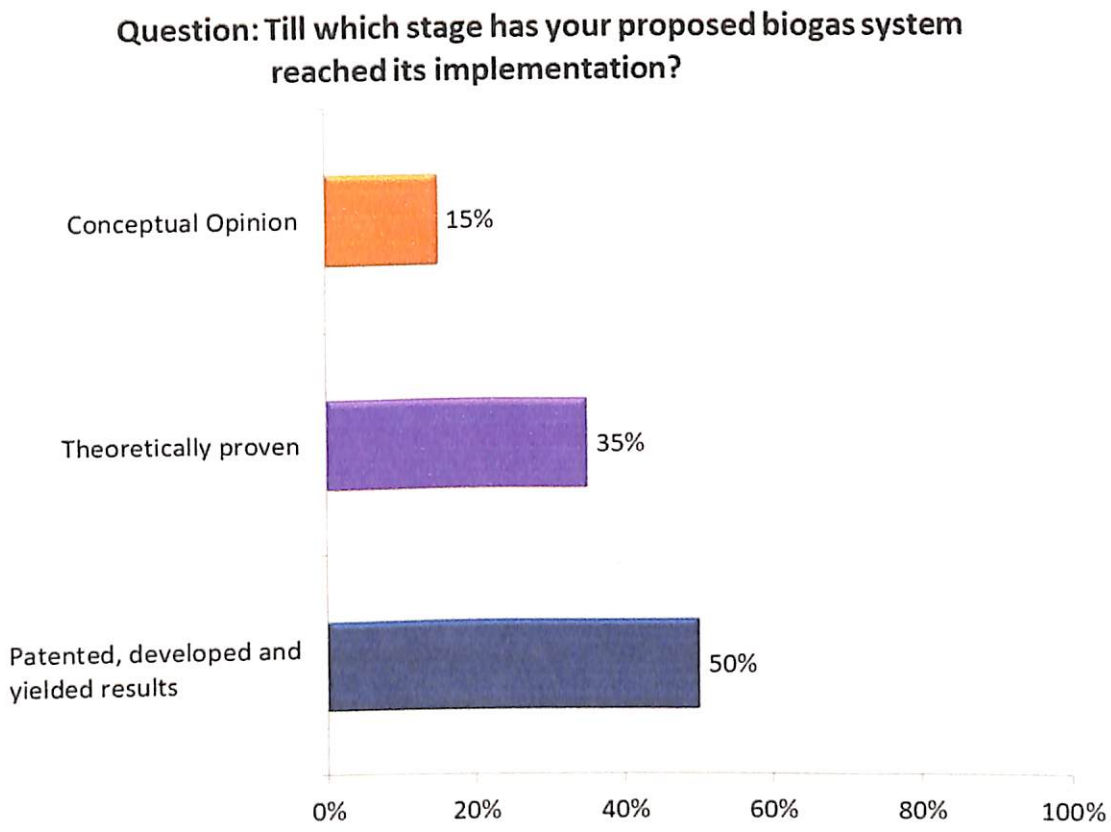

Figure 4.2.3: Application stage of respondent's proposed biogas production system

4.3. Correlation Analysis

This chapter analyses how to variables are strongly related to each other. A positive correlation indicates that those values increases and decrease in parallel whereas a negative correlation indicate the opposite in which one variable increases as the other decreases. When there is a specific fluctuation of one variable causes a similar effect to the other variable either positively or negatively, then the possibility to receive the relation between those two variables is accepted as valid. However, since there may be certain indefinite factors that affect both variables similarly, a correlation may not always imply causation. Nevertheless, correlation is an appropriate technique to prove how strongly two variables are connected to each other. Therefore, the researcher has narrowed down the scope of the variable to be ascertained as the prospect of a rise in average global temperature anomaly in the northern hemisphere (NH) as of where India is situated with the CO_2 emissions from the coal power plant (CPP) in India. The correlation analysis is described in the table and graph below:

Year	Average NH Temperature - median (°C)	CO_2 Emissions from CPP (tonnes)
2000	0.404	633,183,168
2001	0.558	643,354,432
2002	0.593	661,612,144
2003	0.642	691,777,856
2004	0.604	740,498,064
2005	0.724	797,418,304
2006	0.676	854,998,064
2007	0.713	931,165,296
2008	0.569	1,006,673,008
2009	0.594	1,087,530,160
2010	0.74	1,092,637,776
2011	0.575	1,209,849,136
2012	0.627	1,364,667,792
2013	0.674	1,328,844,864
2014	0.779	1,491,530,128

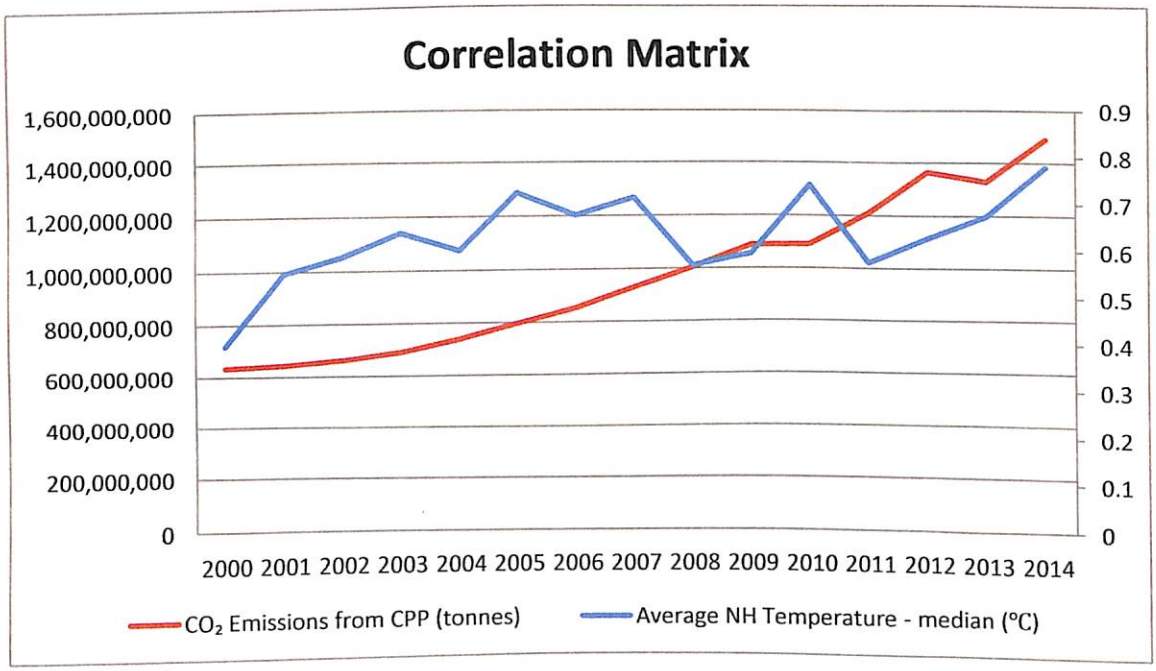

Figure 4.3.1: Correlation Matrix Chart

Therefore, the correlation coefficient formula below is used to calculate the value.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Using Microsoft Excel, below is the result of the correlation value obtained:

	Average NH Temperature - median (°C)	*CO_2 Emissions from CPP (tonnes)*
Average NH Temperature - median (°C)	1	
CO_2 Emissions from CPP (tonnes)	0.47	1

Based on the data above, the result has concluded that the correlation between the rise in average global temperature anomaly in the northern hemisphere (NH) with the CO_2 emissions from the coal power plant (CPP) is positive or in other terms, both variables have a positive relationship from the total 15 variables. Thus, it has been proven that fossil fuel power plants have significantly contributed to global warming. Apart from that, the researcher has specifically chosen coal power plant as the fundamental representative for fossil fuel because the number of development of coal plants has been the highest throughout the years relatively.

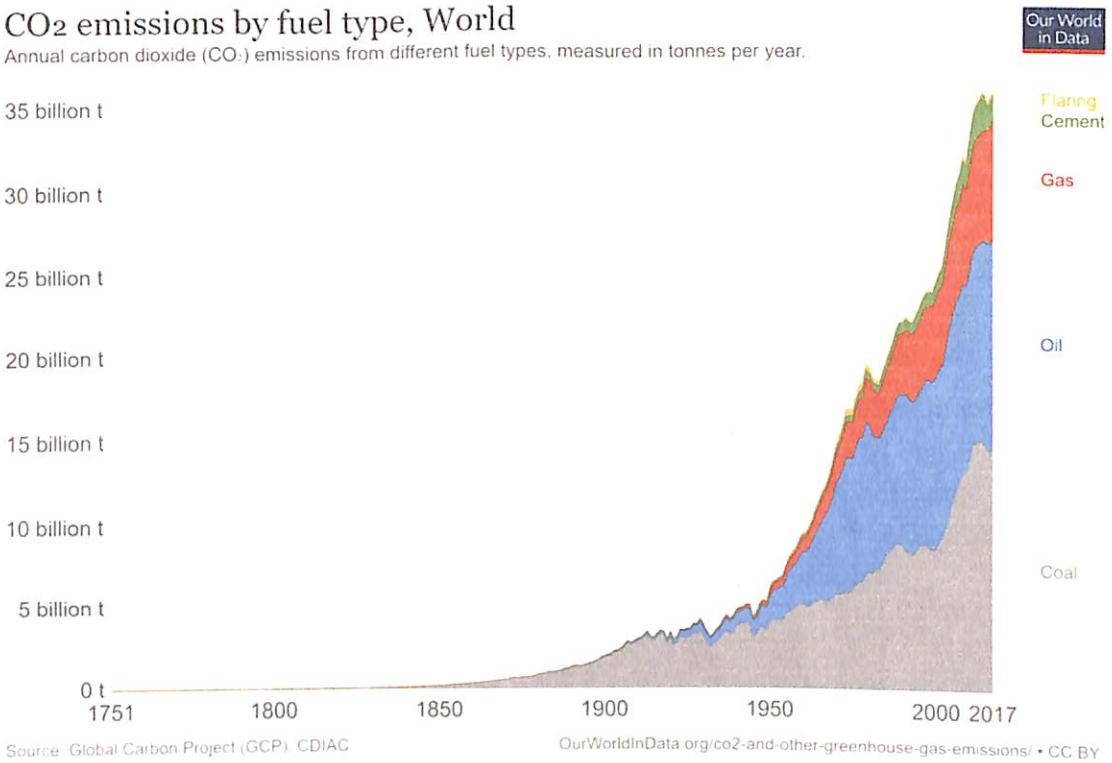

Figure 4.3.2: CO_2 Emissions by Fuel Type

Based on figure 4.3.2, it is comprehended that the highest amount of CO2 emissions is caused by coal amounting up to 15 billion tonnes as of 2017 followed by oil, gas, and others. In India alone, for the year 2014, the coal power plants have emitted 1,491,530,128 tonnes of CO2, followed by 513,689,136 tonnes of CO2 from oil-fuelled power plants and 92,618,592 tonnes of CO2 from gas-fuelled power plants. India has contributed to almost 10% of the global CO2 emissions based on coal power plant which is a noticeable amount.

5. Interpretation of Results

This section of the research shall cover the analysis from results are findings acquired from quantitative and qualitative data which will reflect the insights on Biogas Power Plant Development for India from the perspective and outlook from professionals of various sectors and to what positive impact can these changes deliver to India. Therefore, an online survey by floating interview questionnaires was circulated to the respondents to address each research theme, answering the objective questions, stating their opinions and recommendations based on their viewpoint.

The questions chosen in the online survey interview for the qualitative research were formulated to meet the targets of the research objectives and attain the prospects of answering the main research question. A total of twelve questions were provided to the respondents to observe and understand the respective respondent responses and reactions to the implementation of biogas power plants in India. The respective candidate interviewed is either associated with one of the following organizations:

a) WABIO Technologie GmbH
b) Double Nine Engineering Co.Ltd
c) Indonesia Plantation Synergy Bhd

Every questionnaire integrates an assortment of responses from the different personnel from various departments that will be analysed and discussed. The responses were collected, analysed and compared for each question asked. The results were interpreted and brought about in the following observations. Thus, this interpretation shall be segmented into each research theme for better comprehension results obtained as stated below:

5.1.1. Research Theme 1

Inquiring the respondent's field, nature of background, and thought patterns

The findings have proved that most of the respondents are well versed in the subject of power generation in terms of renewable and non-renewable energy. This is also important for the researcher to ensure that the respondents are qualified enough to meet the objectives of this research. Interviews are particularly useful for getting the story behind a participant's experiences. The interviewer can pursue in-depth information around the topic. Interviews may be useful as follow-up to certain respondents to questionnaires, e.g., to further investigate their responses. (McNamara,1999)

All the respondents have a working experience of more than five years and some had a working experience of more than thirty years. Besides that, all the respondents' minimum qualification was an undergraduate degree and most of them had experiences of handling projects in the Asian region. Therefore, the researcher was able to discern and categorize the respondents from the first part of the research theme in order to identify priority responses in the following themes.

5.1.2. Research Theme 2

Inquiring the respondent's technical knowledge in the field of biogas production systems as well as other power plants

Based on the results, it was perceptible that all the respondents were well versed in the scope of this research subject. Even though the field of expertise might differ based on their respective experience and knowledge, their proficiency was all channelled in the range of power plants which ideally qualifies them for the research theme. The researcher was able to gather and discern essential information from the respondents to analyse and compare the difference between each power plant system and determine which has the most advantageous. There are various factors that encompass this analysis such as financial, economic, social welfare, urban development, safety, agriculture and many more.

In fact, the establishment of a biomass power plant is considered as an effective method to counter the GHG emissions which contribute to global warming in today's world. According to the investigation of Stefan Muench, the direct combustion of biomass for electricity generation is an appropriate approach for GHG mitigation.

Moreover, Saeed Esfandiari of Institute for International Energy Studies (I.I.E.S.) and Ramin Khosrokhavar of Iran Polymer & Petrochemical Institute (IPPI) (2011) have stated that the total GHG emission depending on the particular kind of power plant as of steam turbine shall amount to 621.536 GR/KWh GHG pollutant, 787.056 GR/KWh GHG pollutant for gas turbine, 472.834 GR/KWh GHG pollutant for combined cycle and 778.162 GR/KWh GHG pollutant for diesel-fuelled. On the other hand, biogas power plants for the electricity generation of 1.1 MWh only emits 13,587 tons of CO_2 equivalents GHG pollutants per year which is significantly lesser. In contrast, an average coal-fired power plant emits around 22,560 tons of CO_2 equivalent GHG pollutant for 1MWh of electricity. This shows that coal-fired power plants emit almost 45% more GHG air pollutants compared to a biogas power plant. Based on the information referred to carbon positive life, Ryan McLean (2017) has mentioned that 1 kWh of electricity, when produced from a coal-burning power plant, will generate 0.94 kg (2.07 lbs or 940g) of CO_2 emissions to the atmosphere according to CNCF. Simply multiply your kWh usage (the total will be shown on your electricity bill) by 0.94kg (or 2.07 lbs) to get your total CO_2 emissions.

The findings above are also in confirmation to the statement of Dr. Auerbach (2019) who mentioned that the potential of climatic pollutants in the form of CO_2 equivalents for a biogas power plant per through implementation of latest technology shall be around 25,000 to 26,000 tons per year for a 2MWh electric generation capacity. A biomass power plant with an incineration or gasification system emits around 13,665 tons of CO_2 equivalents GHG pollutants per year for 1MWh capacity which is around 9.6% higher than biogas plant. Although the difference is not considered high, the fuel consumption for a biogas plant to produce 1MWh electricity is lower compared to a biomass combustion power plant. For a biomass incineration power plant, around 1.53 DMT/h of woodchip is required to produce 1MWh electric whereas, for a biogas plant, around 1.25 DMT/h of shredded cotton straw is required to produce 1MWh electric. Not only biogas plant requires lesser fuel for power

generation, but the calorific value of woodchip also ranges between 18 to 21 MJ/kg and the calorific value of dry cotton stalk ranges between 15.861 to 15.100 MJ/kg. With 18% lesser fuel requirement and 28% lower fuel calorific value, a biogas plant is able to generate the same amount of electricity as a biomass combustion plant. Thus, the biogas power plant proves to be the most efficient and profitable system comparatively. Moreover, the researcher is able to interpret that the biogas power plant is the most suitable choice to produce electricity in an environmentally friendly way by considering the utilization of solids as the input fuel.

The construction cost of a biogas plant varies based on the design and nature of the project. A simple agricultural plant could cost as low as USD 3,500 per electrical kW installed. Every project is different. Typical payback on a biogas plant is 7 years. (Electrigaz, 2017). This statement also agrees with the information provided by one of the respondents, Mr. Domogalla who claims that the total cost of constructing one kW electric of a biogas plant would cost around EUR 3,400 to 3,500. Lisa Gibson (2011) mentioned that in 2015 the total cost for a bubbling fluidized bed boiler biomass plant is estimated to be between $3,500 and $4,400 per kilowatt (kW), according to the recent report. Off-shore wind is estimated to cost between $3,100 and $4,000 per kW in 2015, while concentrating solar thermal tips the scale at $3,300 to $5,300 with photovoltaic following close behind at $3,400 to $4,600.

Therefore, the outcome shall determine that the cost of developing a biogas production plant is almost equivalent to other existing systems in the power industry. Besides that, the development of biogas power plants yields various advantages for the farmers from the production of NPKS fertilizers, says one of the respondents, Varun (2019). After the fermentation substrates have undergone various fermentation processes to produce methane, the material goes through a phase separation process to separate the liquid and the solids from the fermentation residues. The solids separated contain approximately 30% dry matter content and it is rich with nitrogen, phosphorus, potassium and sulphur properties. This organic fertilizer is very suitable for the growth of plantation and it can be converted into different forms such as pellet or powdered, depending on the requirement. By selling this fertilizer, it will generate greater revenue to the owners of the biogas power plant or if the owner owns any agriculture business, it can be applied on the plantation to produce better crops and make more profit.

Otherwise, the NPKS fertilizer can also be returned to the farmers who supply the fresh material for biogas production where payment terms can be negotiated based on the incoming and outgoing basis. This initiative will support the farmers to reduce the necessity to spend an additional cost to purchase chemical fertilizers by which most of them can't afford and also this provision shall generate more revenue for the farmer through producing more plantation crops. Since the scale of plantation increases, the fuel input for the biogas power plant will proportionately increase as well. This chain-reaction will enable the owner of the biogas plant to increase its capacity and make more profit through selling electricity to the national grid and sales of fertilizers. Teodorita Al Sead and Dominik Rutz (2008) have stated that a biogas plant is not only a supplier of energy. The digested substrate, usually named digestate, is a valuable soil fertiliser, rich in nitrogen, phosphorus, potassium, and micronutrients,

which can be applied to soils with the usual equipment for the application of liquid manure. Compared to raw animal manure, digestate has improved fertiliser efficiency due to higher homogeneity and nutrient availability, better C/N ratio and significantly reduced odors.

5.1.3. Research Theme 3

Inquiring the respondent's opinion and idea of which power production system will yield more benefits and is more advantageous for India

A substantial number of respondents agree that energy investors in India are quite sceptical to develop a biogas power plant due to the bad track record of the performance from previous biogas power plants in India. They claim that the innovation factor of biogas industries in India has been minimal and not pursued widely by setting up research and development institutes, introduction to new technologies and also lack of encouragement for foreign investment or expertise to establish their business in India. Certain respondents claim that the operational and maintenance cost of the old conventional biogas power plants in India is very high due to the lack of proper planning, no considerable agreement or contract between the fuel suppliers and biogas plant owners, choices of old technologies which causes various operational and maintenance issues, wrong selection of equipment such as pumps, blower which inevitably leads to reaching a longer payback period and break-even point.

It is very necessary for the interference of government sectors into the biogas development industry to motivate other energy investors or likewise business owners to invest in this diligence. In line with the statement of Mr. Sukarno (2019) where he mentions that a pilot biogas plant should be developed and tested on a small scale at first to observe the performance of the technology. All R&D should be conducted in the pilot-plant to determine which nature of the operation is most suited for the Indian market. Once these benchmarks are identified, then large scale development can be implemented all over India. The biggest motivational factor for the biogas power plant industry to be successful in India is that the agriculture sector is large and since there are a large number of people who consumed various kinds of vegetables for their food, high amount of fresh material can be recovered from MSW once it is sorted. The wasted products of the plantations once the crops are harvested and the fresh material recovered from the MSW is rich with organic content which is the most significant factor for biogas production. Apart from that, the treatment cost for these sources of fuel is not required for a biogas power plant because it can be fed into the system in a wet form or high moisture content. Therefore, the fuel preparation systems and costs are excluded.

Many respondents claim that there were many maintenance issues due to solidifications of materials inside the digester tank due to lack of agitation inside the tank and homogeneousness of feeding substance. As for this issue, Dr. Auerbach (2019) has mentioned that such problems do arise due to the absence of the latest shredding technologies, latest vertical mixers and submerged agitators, feeding material hydrolysis system and hydraulic fermenters with bottom vortex mixers. Through the establishment of all these latest technologies, solidification problems that can cause various O&M and financial

constrain can certainly be evaded. The flow chart of a biogas power plant with the most updated system for a 2MWh electric pilot project is shown below:

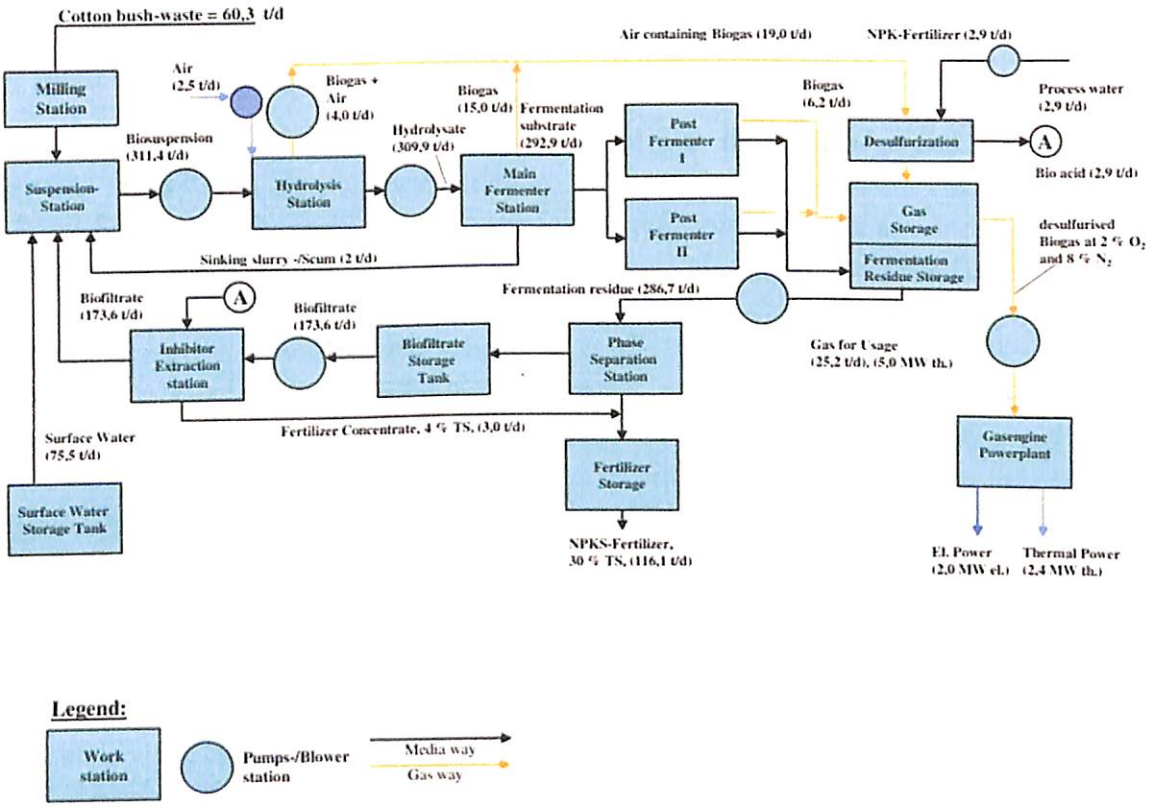

Figure 5.1: The ideal system for a 2.0MW electric pilot biogas power plant for India

Apart from that, the old conventional biogas systems in India either rely solely on anaerobic bacteria culture in a mesophilic environment to generate biogas. However, in the latest technology, it includes the combination of the aerobic and anaerobic systems as well as a combination of mesophilic and thermophilic bacteria cultures for a more optimum and greater methane gas production. As per the statement of Ms. Amornrat (2019), she mentions that by implementing the latest technologies, it could significantly reduce the payback period and attain break-even point lesser than 7 years. Hence, the researcher is able to interpret that a pilot plant is vital for the development of the biogas industry in India. The pilot plant should include the combination of aerobic and anaerobic fermentation technologies and the mixture of mesophilic and thermophilic bacteria cultures as the most ideal gas production method for India.

5.2. Comparison of Results with Assumptions (Hypothesis)

5.2.1. First Research Hypothesis

The first research hypothesis relates to the environmental advantages gained:

- **Biogas power plant emits lesser greenhouse gas into the atmosphere compared to fossil fuel power plants thereby makes it more environmentally friendly**

Based on the interpretation of results, it has been proven that biogas power plant emits significantly lesser GHG air pollutant emission in terms of CO_2 equivalent compared with other fossil fuel power plants. The reduction of GHG pollutant emission of a biogas plant is comparatively 55% lesser compared to a coal-fired power plant. Due to the emission caused by fossil fuel power plants, Sarath K. Guttikunda and Puja Jawahar (2014) from Division of Atmospheric Sciences, Desert Research Institute, Reno, NV 89512, USA has stated that in 2010 - 11, 111 plants with an installed capacity of 121 GW, consumed 503 million tons of coal, and generated an estimated 580 ktons of particulates with diameter less than 2.5 mm (PM2.5), 2100 ktons of sulfur dioxides, 2000 ktons of nitrogen oxides, 1100 ktons of carbon monoxide, 100 ktons of volatile organic compounds, and 665 million tons of carbon dioxide.

These emissions resulted in an estimated 80,000 to 115,000 premature deaths and 20.0 million asthma cases from exposure to PM2.5 pollution, which cost the public and the government an estimated INR 16,000 to 23,000 crores (USD 3.2 to 4.6 billion). Thus, the pollution effect from these coal power plants in India has caused severe health issues and due to that, the government had to spend a considerable amount of money to tackle these concerns. Additionally, the image below displays the GHG emissions of various power plants in terms of tonnes of CO_2 equivalent per GWh generated:

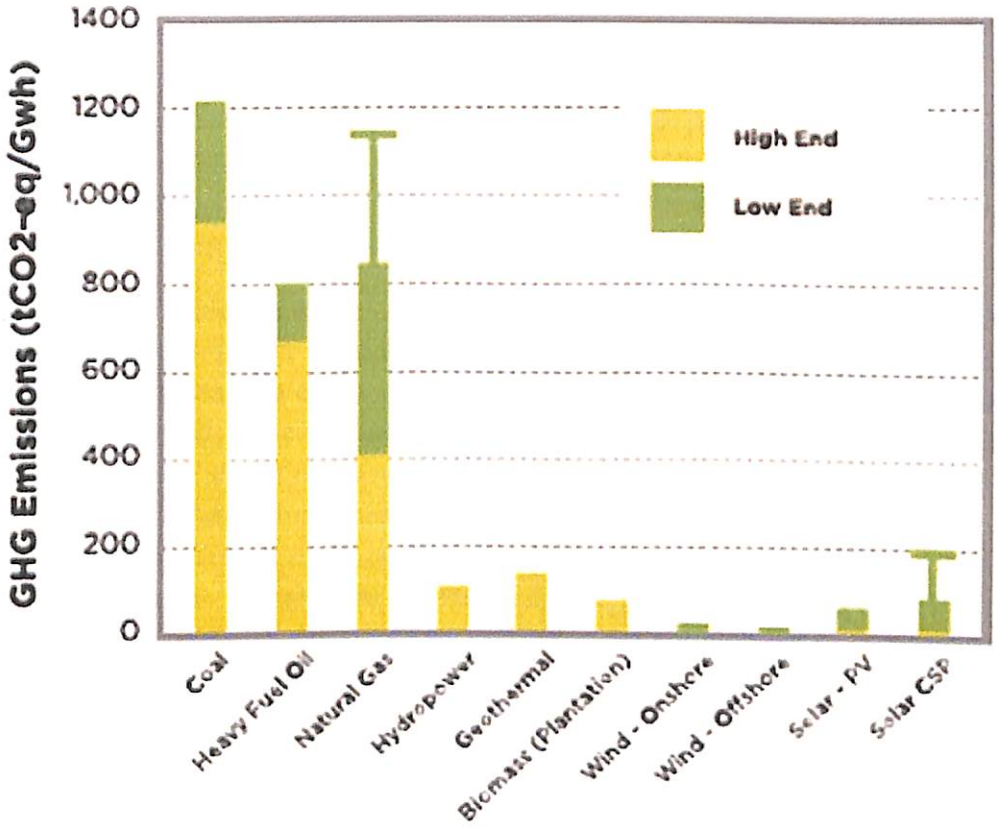

Figure 5.2.1: GHG Emissions of various Power Plants

From the image above, it is clear that coal power plant emits the highest amount of GHG air pollutants followed by other fossil fuel power plants.

5.2.2. Second Research Hypothesis

The second research hypothesis relates to the financial and economic advantages gained:

- **Biogas power plants are able to generate greater revenue whereby the construction costs are lesser and the payback period is faster compared to fossil fuel power plants**

Since India is highly dependent on the imports of coal for power generation, the quality of the coal imported plays a very significant role in determining the payback period and reaching the break-even point. In other words, the moisture content in the imported coal is the deciding

factor for the performances of the coal plant because of the lesser the moisture, the higher the efficiency of the boiler. Mr. Anjan Bhattacharya (2016) from TATA Consulting Engineers Ltd, has mentioned that for a typical sub-bituminous coal-fired boiler, 10% moisture reduction in coal improves boiler efficiency by about 1.5 percentage points and plant efficiency by about 0.6 percentage points. Besides that, he also mentions that India is now importing large amounts of high moisture low-rank coal, there is growing interest in the potential benefits of drying the fuel prior to combustion.

In order to tackle this issue, most coal-fired power plants in India are equipped with drying facilities to reduce the moisture content in the coal prior to feeding it into the boiler. The development and operation cost of these facilities requires a substantial amount that directly affects the payback period. Nevertheless, with or without the coal drying treatment facilities, the payback period of a coal-fired power plant remains higher than a biomass or biogas power plant. A typical conventional biogas plant requires around 7 years of payback period and a more updated system with the latest technologies would require lesser than 7 years, probably close to 6 years. Whereas for a coal-fired power plant, it would entail a payback period of at least 7.5 years if the coals are to be dried at the mining area or 17.5 years if the coal has to be dried on-site.

Although the construction cost of a biogas power plant is estimated to be USD 3,500 per electrical kW installed which is almost similar compared to a coal-fired power plant whereby the construction cost is estimated to be around USD 3,500 per electrical kW. Based on an article from Synapse Energy Economics by David Schlissel, Allison Smith and Rachel Wilson (2008), they have stated that the estimated cost for this Circulating Fluid Bed plant is above $3,500/kW, in early 2008 dollars. The company has similarly estimated that the cost of building a new supercritical coal plant also would exceed $3,500/kW. Therefore, since this statement was declared in 2008, it has been more than 10 years now and surely the construction cost would have exceeded more than USD 3,500 per electric kW, not forgetting to also consider the additional treatment cost required to dry the wet coal imported by India. However, the investment criteria require a more dynamic approach which shall deal with a consideration of benefits and costs over several years for a more detailed analysis. In the investment criteria should be taken into account the Net Present Value (NPV) by which the formula is explained below:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+k)^t}$$

NPV - Net Present Value

C_t - Costs in year t

B_t - Benefits in year t

k - discount rate

t - number of years from the present

n - total number of the years of the analysis period

Relatively, the Internal Rate of Return (IRR) value to invest in a biogas power plant project should be at least 10%. Teodorita Al Sead and Dominik Rutz (2008) have stated that if the project obtains an internal rate of return (IRR) lower than 9%, you should reconsider all the project premises, and improve some of them. If the IRR rate is higher than 9%, the premises are good and it is worth continuing the project and moving to the next planning phase.

5.2.3. Third Research Hypothesis

c) The third research hypothesis relates to the community and social advantages gained:

- **Biogas power plants are easier to implement in small and large scale thereby makes it more preferable in rural areas to promote agriculture, waste management, and job opportunities**

The flexibility to implement a biogas power plant is very wide in which it can be constructed as a family-scale biogas plant to an industrial biogas plant. The range of workability is possible because the process of producing biogas is straight forward and the equipment required to construct a biogas plant can be uncomplicated, affordable, robust, basic operation and maintenance, and the material needed for construction can be procured locally. In line with the above statement, Teodorita Al Sead and Dominik Rutz (2008) have mentioned that in countries like Nepal, China or India operate millions of family-scale biogas plants, utilising very simple technologies. The AD feedstock used in these biogas plants originates from the household and/or their small farming activity and the produced biogas is used for the family cooking and lighting needs.

There are also various options available to develop a farm-scale biogas power plant in correspondence with the type of waste that can be derived from the respective farm. Biogas plants have the benefits of mixing various kinds of organic wastes in different forms regardless of the moisture content because it deals with wet fuel for the fermentation process. The scale of the biogas plant is determined based on the capacity of the farm. It is also dependent on the designs, technologies, and level of complexity. Certain plants are straightforward for generating the biogas whereas there are also other systems which include complicated recycling facilities such as inhibitor extraction system which is intended to treat the liquid biofiltration to eliminate specific substance such as ammonia so that it can be recycled into the digester. These facilities are provided to reduce the dependence of the biogas plant on external sources thereby making it more self-sufficient. There are options to develop co-digestion biogas plant through the combination of 2 or more substrates such as silage derived from plantation and animal manures and slurries collected from several farms. As mentioned by Rudolf Braun and Arthur Wellinger (2014) of IEA-Bioenergy, the most common situation is when a major amount of a main basic substrate (e.g. manure or sewage sludge) is mixed and digested together with minor amounts of a single, or a variety of additional substrates. The expression co-digestion is applied independently to the ratio of the respective substrates used simultaneously.

Besides, biogas systems are largely established in waste water treatment plants. The sludge skimmed from the aerobic treatment process of municipal waste water undergoes primary and secondary treatment phases in anaerobic digester to produce biogas. There are various advanced designs combined with the biogas power plant such as nitrification and denitrification system to treat the waste water before discharging as per the respective country regulation. As stated by Dominik Rutz (2008), in European countries, between 30 and 70% of sewage sludge is treated by AD, depending on national legislation and priorities. Taking into account the need for modern urban development to raise with the occasion and requirement of metropolitan cities in India such as electricity deficit, biogas power plant serves as the most ideal option to fulfil the demands. However, a suitable recycling system coupled with waste sorting facilities should be implemented to organize the appropriate feedstock for the biogas plant. Based on the population of a particular city, the proportion of organic collected will almost be similar. Moreover, there are advantageous associated with waste to energy through biogas concept.

MSW to biogas is a new concept. Developed countries have taken the lead to treat the bio-degradable MSW through anaerobic digestion. The sludge from anaerobic digestion can be sold as manure. Other major advantage of MSW to biogas is the reduced land requirement. Compared to landfill, the size of MSW biogas plant is very small. This approach involves segregation of biodegradable waste such as vegetable, food waste, etc. from MSW and using it in a biogas reactor to produce biogas.

Biogas plants have been largely developed along with several industrial sites to treat the chemical wastes and/or waste waters prior to discharging it to the environment. It is a standard integrated technology for the treatment of various industrial waste waters deriving from food-processing, agro-industries, and pharmaceutical industries. The concept is also very profitable as biogas power plant will not only treat the waste efficiently, it will also generate income through the sale of electricity or provision of electricity for operation of the respective processing plant. It reduces the cost for disposing the waste as well as adds value through nutrient recycling. Moreover, anaerobic digesters can be applied to pre-treat organic loaded industrial waste waters before disposing it to the environment. When such is initiative taken to practice environmental friendly treatment of the produced waste, the concerned industry image will improve and be a role model to other industries. In an article written by Markus Ellersdorfer and Christian Weiss in 2011, they mentioned that the paper quantifies the synergy-effects of an areal combination of biogas-plants with plants of the building materials industry (e.g. cement plants) from the energetic and economical point of view. Therefore a model biogas and cement plant are defined and the effects of a combination of both plants in terms of energetic efficiency, investment and operating costs, greenhouse gas emission reduction and overall energy production costs are quantified.

Last but not least, landfills can also be considered as biogas generation plants. Even though the composition of the landfill gas is similar to biogas, but due the waste material decomposition process, the landfill gas may contain toxic substances. The decomposition process which takes place in a landfill is irregular it is also depends on the oldness of the establishment. Therefore, by implementing suitable gas treatment facilities in place, the

generated landfill gasses can be recovered and treated for power generation. Such practice shall eliminate GHG pollutant emissions and it also a cheap and simplified source of energy available in abundance.

Mohammad javad Asgari (2011) of Islamic Azad University, Isfahan, Iran, mentions that the present municipal solid waste landfills generate biogas and leachate. Due the amount of waste, biogas production represents a very promising way to solve the problem of waste treatment. Furthermore, the solid residuals of fermentation might be reused as fertilizers.

6. Conclusions and Scope for Future Work

This research is mainly intended to highlight the benefits a nation like India can derive by implementing biogas power plants from the abundant resources it currently contains. India has already been introduced to the concept of biogas technology. However, the existing conventional systems are backdated and have various operational and maintenance issues. Besides that, other accompanying factors have caused this industry not to prosper in India such as corruption, tedious public hearing, civil irresponsibility, inconsistent social culture, political instability and many more. Considering that India now is moving towards a more positive direction and it is rapidly growing with widespread information access through social media and digitalization of data transfer, the public is gaining more awareness to assimilate the knowledge it covers worldwide. People are becoming more concerned about the environmental challenges India is currently facing and how to overcome these issues appropriately.

With the latest technology which biogas power plant offers, India can solve most of its critical problems and set an example as a leading nation that has successfully utilized all of its waste materials in a most effective manner, such as by converting waste to energy (WTE). The biogas power plant is able to consume almost any fuel which has organic matter content and its process flow is straight forward. The design of the plant capacity is flexible and can be constructed and operated within a short period. Therefore, the applied design of an existing plant can be cloned into various locations to cater to the requirements based on the specific areas. Biogas production plants are suitable to be operated in urban cities as well as rural areas as long as a steady input of fuel should be always available. The Indian government should encourage the establishment of such green energy development projects by providing better feed-in-tariff rates and issue bonuses to support other related Indian industries such as equipment manufacturers as a starting point.

Moreover, biogas power plants can unravel the current distress Indian farmers are facing as a majority of them complain that they are not earning enough profit from their business and hard work. With a biogas power plant readily available around the premises, they can sell the waste materials from the plantation which is a source of fuel for energy production and generate more revenue instead of open burning and cause air pollution. The final product from the fermentation residue can be distributed as organic fertilizers for the farmers to apply

on their plantation and yield better results. Due to the population crisis in urban cities, India authorities are finding it very difficult to manage the municipal waste suitably. As mentioned above, India could outsource private companies to collect all waste, sort it and sell it to a biogas power plant. The plant could generate sufficient power for the public because the proportion of waste also corresponds with the level of the population accordingly. Thus, power deficit and failures can be prevented and open a wider scope for foreign investors to venture into the Indian market can be heightened by opening a manufacturing plant and furthermore. India could also gradually reduce its dependence on fossil fuel by developing more biogas power plants. This shall reduce its requirements to allocate a huge amount of funds to purchase fossil fuels. It shall thereby boost its economic growth because biogas fuel requirement is easily and cheaply available. Apart from that, the export industry of India will also grow simultaneously through the greater cultivation of agricultural industries and organic fertilizer production which will further strengthen India's economy and generate more revenue. The researcher expects this study to reach energy investors and government bodies of India to consider the advantageous biogas power plant offers to the nation and take this concept to the next stage of expansion.

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8. Appendix

Online Survey Cover Letter

Dear Participant,

I hope this mail finds you well.

My name is Gowree Sankaran and I'm currently pursuing my Masters in Power Management at the University of Petroleum and Energy Studies (UPES), India. As part of my curriculum, I am undertaking an online survey on the Benefits of Developing Biogas Power Plant to Solve Energy Deficit and Promote Economic Growth in India.

The survey is designed to gather information on the viewpoints and suggestions of professionals in the field of power plant industries for a broad understanding and assimilation to serve as guidance for my dissertation. The online survey is estimated to take around 15 to 30 minutes.

You may decide to stop being a part of the survey at any time without any explanation required from you. You have the right to ask that any data you have supplied to that point may be withdrawn. You have the right to omit or refuse to answer or respond to any question that is asked of you.

I am so thankful to you for taking the time to answer this survey questionnaire. Your information will remain confidential and only be used for academic purposes.

If you have any questions or concerns regarding the survey, please feel free to ask me.

Email: shankra07@gmail.com

Sincerely,

Gowree Sankaran

Online Survey Questionnaire

Name: Benard Stollberg

Company: Wabio Technologie GmbH

1. What is your past working experience?
   Ans.: I've worked in many biogas plant construction projects. In those projects I was involved in all phases starting from design and engineering till construction and operation. I have also done a few researches in the scope of biogas plant input to integrate various types of fuel for higher gas production.

2. In which departments have you worked till present?
   - [x] Project Management
   - [ ] Engineering
   - [ ] Procurement
   - [x] Construction
   - [x] Commissioning and/or operation
   - [ ] Business Development
   - [ ] Contract Management
   - [x] Others (Please Specify) - Research & development

3. What is your academic background?
   Ans.: I possess a Master Degree in Chemical Engineering

4. What is your opinion about power generation in terms of renewable and non-renewable?
   Ans.: Considering the current issues the society is facing due to global warming which leads to various natural calamities such as raise in the sea level, air pollutant from GHG emissions, air and waterborne diseases and many more, renewable energy will be the opted choice for a healthy lifestyle.

5. What is your opinion about the power industries and potentials in the Asian market?
   Ans.: Asia has a very high potential to grow in the power industry because it has abundance of resources and it has a stable weather condition unlike other continents. Asia also possesses a growing number of talents to contribute to the power industries and a rising economy.

6. What is the most suitable method of generating power in terms of electricity for the Indian regions?

Ans.: Biogas power plant will be the most suitable method because India has high agriculture production industries which can cater a high fuel input for the plant. If you want to compare with biomass boiler, it is only limited to dry fuels. India also has a high poultry farms to rare cows especially for the milk production. The manure from the cow farms also serves as a good fuel to combine with agricultural waste to generate power. So biogas system is the most ideal. India does not have sufficient resources of fossil fuels so it's not in consideration.

7. Have you been involved in a biogas power plant construction project? If yes, please state the nature of the project and your job scope.
Ans.: Yes. The nature of projects involves biogas systems which take in fuel from agricultural waste, poultry farms waste, industrial waste and MSW. I was involved in the engineering, procurement, construction, commissioning and operation stages.

8. What kind of problems have you encountered while developing the biogas power plant and how have you solved those problems? Otherwise, other power plants which you had experienced.
Ans.: I will state 1 problem here. We have developed a technology to recycle the fermentation substrate after undergoing the whole fermentation substrate. But in a project, the owners decided to not implement the recycling system. One day, the power plant did not have enough process water to prepare the fuel for the fermentation. So they decided to directly recycle fermentation substrate as a temporary measure. Later on, the gas production dropped almost 50% because the fermentation substrate contained ammonium substance which a major inhibitor for gas production. Once we found out this problem, an inhibitor extraction system of our technology was installed and the water consumption was highly reduced and the plant was performing well again.

9. Do you agree that the biogas power plant is a suitable method to generate electricity in India? Please provide an explanation for your answer.
   - [x] Agree
   - [ ] Disagree
   - [ ] Neutral

Ans.: Explained in question No.6.

10. What is the most efficient process flow technology you suggest to be implemented in India?
Ans.: I would suggest hydraulic fermenters with combination of hydrolysis and inhibitor extraction system. But the EPC contractor should study and understand the nature of business in India as well as their working culture. Therefore, it will be easier to succeed in the project by making a joint venture or consortium with an

Indian company to develop a biogas plant in India. Biogas power plant which relies on agricultural inputs needs close cooperation with farmers to ensure a steady input. So, such agreements can be accomplished by the Indian partner effectively. Through this method, the above-mentioned process flow technology can be realised.

11. What is the difference between the process flow you suggested and other conventional systems?
Ans.: A conventional system consists of mixed or plug-flow digesters which are prone to solid accumulation and not as efficient as hydraulic fermenters and other biogas plant don't have a separate hydrolysis and inhibitor extraction station.

12. Please explain the overall plant efficiency as well as energy balance and describe how the proposed system is more effective compared to other conventional systems.
Ans.: By introducing a hydrolysis system, fuel with higher lignocellulose level can be used and inhibitor extraction system recycles the fermentation substrate back to the biogas plant. Hydraulic fermenter has advance mixing technology and bacteria cultivation phases to produce higher volume of methane gas. So the turnover will be higher through the production of higher gas volume, usage of various fuels and lesser consumption of water.

13. To which stage has your proposed biogas system reached its implementation? Please select the categories below:
- [x] Patented, developed and yielded results
- [ ] Theoretically proven
- [ ] Conceptual Opinion

14. What are the overall benefits of implementing a biogas power plant in India?
Ans.: Mainly are the economic benefits. India may stop relying on heavy foreign imports for fossil fuels. Biogas industries promote agricultural growth so it generates more revenue. Additionally, biogas plant can be constructed in various sizes so it can ensure stable power supply to the other businesses to grow thereby providing more employment opportunities. The construction of biogas plants will increase the air quality by lessening the GHG air pollutions and also improve the health conditions of the people.

15. Do you think India is prepared to make a shift towards investments in the renewable energy sector and mainly biogas power plant projects considering its current market condition, investment preference, social culture, and political stability?
Ans.: Yes. The growing population of India demands more power requirements and also job opportunities. India should have invested in biogas plants much earlier. I'm not very sure about India's political condition but I think the people

now are more united than before. So it will serve as a common interest for development. A survey has indicated that India will have a GDP growth of 7% in 2020 which is the highest compared to other countries and have a rapid economic expansion. So things seem to look positive for India for the coming years.

Gas yield and methane yield from various types of farm manure

Substrate		Biogas yield [Nm³/t substrate]	Methane yield [Nm³/t substrate]	Specific methane yield on VS basis [Nm³/t VS]
Cattle slurry	Δ	20-30	11-19	110-275
	∅	25	14	210
Pig slurry	Δ	20-35	12-21	180-360
	∅	28	17	250
Cattle dung	Δ	60-120	33-36	130-330
	∅	80	44	250
Poultry manure	Δ	130-270	70-140	200-360
	∅	140	90	280

Δ: range of measured values; ∅: average

Biogas yields of selected energy crops

Substrate		Biogas yield [Nm³/t substrate]	Methane yield [Nm³/t substrate]	Specific methane yield on VS basis [Nm³/t VS]
Maize silage	Δ	170-230	89-120	234-364
	∅	200	106	340
WCC silage	Δ	170-220	90-120	290-350
	∅	190	105	329
Cereal grains	∅	620	320	380
Grass silage	Δ	170-200	93-109	300-338
	∅	180	98	310
Sugar beet	Δ	120-140	65-76	340-372
	∅	130	72	350
Fodder beet	Δ	75-100	40-54	332-364
	∅	90	50	350

Δ: range of measured values; ∅: average

Technical and process-related parameters of model plant

Technical and process-related data	Unit	X Gas processing
Nominal capacity	m^3/h	500
Average flow rate	m^3/h	439
Capacity utilisation	h/a	7,690
Consumption of biogas for digester heating	%	5
Methane loss	%	2
Calorific value of raw gas	kWh/m^3	5.2
Calorific value of purified gas	kWh/m^3	9.8
Calorific value of feed-in gas	kWh/m^3	11.0
Gross digester volume	m^3/h	7,400
Digestate storage volume	m^3/h	6,800
Dry matter content of substrate mixture (incl. recirculate)	%	30.6
Average hydraulic retention time	d	110
Digester organic loading rate	kg $VS/m^3 \cdot d$	2.5
Raw gas	m^3/a kWh/a	3,652,570 19,021,710
Purified gas	m^3/a kWh/a	1,900,128 18,621,253
Feed-in gas	m^3/a kWh/a	2,053,155 22,581,100

Cost/revenue analysis for model plants

Cost/revenue analysis	Unit	100% energy crops 500 kW_{el}	Biowastes 500 kW_{el}	100% energy crops 1000 kW_{el}	Dry digestion 500 kW_{el}
Revenues					
Electricity fed in	kWh/a	4,013,453	4,001,798	8,009,141	4,002,618
Average tariff	ct/kWh	18.52	11.66	15.93	18.52
Sale of electricity	€/a	743,194	466,606	1,276,023	741,274
Sale of heat	€/a	27,525	27,450	49,900	27,455
Total revenues	**€/a**	**770,719**	**494,055**	**1,325,922**	**768,729**
Variable costs					
Substrate costs	€/a	335,818	40,000	638,409	348,182
Consumables	€/a	51,807	57,504	106,549	50,050
Repairs and maintenance	€/a	78,979	76,498	152,787	81,876
Laboratory analyses	€/a	1,440	1,440	2,880	1,440
Total variable costs	**€/a**	**468,045**	**175,442**	**900,625**	**481,548**
Contribution margin	*€/a*	*302.674*	*318.613*	*425.297*	*287.182*
Fixed costs					
Depreciation	€/a	135,346	143,657	226,328	147,307
Interest	€/a	32,746	35,255	54,299	41,284
Insurance	€/a	8,187	8,814	13,575	10,321
Labour	work hrs./d	7.24	6.31	11.19	9.41
Labour	work hrs./a	2,641	2,304	4,086	3,436
Labour	€/a	39,613	34,566	61,283	51,544
Total fixed costs	**€/a**	**215,893**	**222,291**	**355,485**	**250,456**
Revenues w/o direct costs	*€/a*	*86.781*	*96.322*	*69.812*	*36.725*
Overheads	€/a	5,000	5,000	10,000	5,000
Total costs	€/a	688,937	402,733	1,266,110	737,004
Electricity generation costs	ct/kWh_{el}	16.48	9.38	15.19	17.73
Profit/loss	**€/a**	**81,781**	**91,322**	**59,812**	**31,725**
Return on total investment	**%**	**14.0**	**14.4**	**8.4**	**7.1**