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FUELING THE FUTURE: A REPORT ON BIOCNG

With Best Practices and Case Studies

December 2023

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ACRONYMS & ABBREVIATIONS

APS	Announced Pledges Scenario
BGF	Biogas Guarantee Facility
BioCNG	Biomethane Compressed Natural Gas
BioCNH	Biomethane Compact Natural Hydrogen
BioLNG	Bioliquefied Natural Gas
CAPEX	Capital expenditure
CGD	City gas distribution
CNG	Compressed Natural Gas
COD	Chemical oxygen demand
EBG	Enriched biogas
EEC	Eastern Economic Corridor
EJ	Exajoule
EPC	Engineering, procurement and construction
FAO	The United Nations Food and Agriculture Organization
FDI	Foreign Direct Investment
FOM	Fermented organic manure
GGCS	Green Gas Certification Scheme
GGGI	Global Green Growth Institute
GHG	Greenhouse gas
GIS	Geographical information system
GoI	Government of Indonesia
HAREDA	Haryana Renewable Energy Development Agency
HORECA	Hotels, Restaurants, and Cafes
HSAD	High Solids Anaerobic Digestion
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPL	Indian Potash Limited
IRR	Internal Rate of Return
ISN	Indonesian National Standard (Standar Nasional Indonesia)
ISP	Integrated Solution Provider
ISPL	Integrated solution provider-led
ISRR	Investor-led shared risk
ITMO	Internationally transferred mitigation outcomes
JETP	Just Energy Transition Partnership
KESDM	Indonesia's Ministry of Energy and Mineral Resources (Kementerian Energi dan Sumber Daya Mineral)
LBG	Liquefied biogas
LFOM	Liquid fermented organic manure
LNG	Liquefied Natural Gas
LoA	Letter of Allocation
LOI	Letter of intent
LPG	Liquefied Petroleum Gas
MEMR	Ministry of Energy and Mineral Resources
MJ	Megajoule
MoPNG	Ministry of Petroleum and Natural Gas
MoU	Memorandum of Understanding
MSW	Municipal solid waste
NDC	Nationally Determined Contributions
NG	Natural gas
NGV	Natural gas vehicle

NPV	Net Present Value
O&M	Operations and maintenance
OMC	Oil and gas marketing companies
ONEP	Office of Natural Resources and Environmental Policy and Planning
OPEX	Operating expenses
PFR	Pre-feasibility report
PLN	Indonesian State Electricity Company (Perusahan Listrik Negara)
POM	Palm oil mills
POME	Palm oil mill effluent
PPP	Public-private partnership
PRS	Pressure regulating stations
PSA	Pressure swing adsorption
REOI	Request for Expressions of Interest
RSPO	Roundtable on Sustainable Palm Oil
SATAT	Sustainable Alternative Towards Affordable Transportation
SFOM	Solid fermented organic manure
SPV	Special Purpose Vehicle
SRR	Shared risk-return
THB	Thai Baht
TOP	Tap off point
TPD	Tonnes per day
UASB	Upflow Anaerobic Sludge Blankets
VER	Voluntary Emission Reductions

CONTENTS

Executive Summary

In today's world, we face interconnected challenges such as climate change, air pollution, and resource scarcity, requiring immediate and innovative action. BioCNG, derived from renewable biogas, offers a promising solution for a cleaner, greener, and more resilient future.

Biogas, sourced from organic biomass like agricultural residue, vegetable waste, sewage, and municipal solid waste, is processed in oxygen-free 'biogas digesters.' The resulting mixture, mainly methane and carbon dioxide, is a clean, renewable fuel, emitting fewer pollutants than traditional fossil fuels. BioCNG is produced by removing impurities from the biogas and compressing it for packaging in cylinders or pumping into a natural gas grid. It is ideal for automobiles, as an industrial fuel and in power plants as a replacement for natural gas. Importantly, biogas and BioCNG are not classified as greenhouse gases.

The Global Green Growth Institute (GGGI) actively supports BioCNG development in India, Thailand, and Indonesia through its BioCNG Global Program. The initiative aims to create an enabling business environment, reduce barriers to BioCNG use, and promote environmentally sustainable and commercially scalable business models.

This report summarizes the program's experience, offers policy recommendations, and provides guidance to GGGI Country Teams and stakeholders on developing effective BioCNG projects. It covers policy and regulatory frameworks, business models, financing mechanisms, technology options, market analysis, and sustainability assessment. Overall, the report finds that establishing a thriving, sustainable BioCNG sector presents both developed and developing countries with substantial environmental, social, and economic benefits.

Environmentally, BioCNG offers significant outcomes. As a renewable and low-carbon fuel, BioCNG helps reduce greenhouse gas emissions, mitigating climate change. Using BioCNG instead of fossil fuels improves air quality by lowering emissions of pollutants and particulate matter. Also, producing BioCNG is generally less water-intensive than conventional energy production processes relying on water for cooling and other purposes. BioCNG's economic advantages are worth noting. By using organic waste, BioCNG can help close the loop of the linear waste economy, reintroducing organic matter into the value chain and creating a circular economy that promotes resource efficiency and waste reduction. Furthermore, a strong BioCNG sector can generate jobs across the value chain, including waste collection, transportation, biogas production, and distribution, as well as in the manufacturing and maintenance of biogas equipment and vehicles.

A strong BioCNG sector also has social advantages. BioCNG production provides a source of income for farmers and rural communities who can sell their organic waste to BioCNG operators. In rural areas with limited access to electricity and clean cooking fuels, BioCNG can provide a reliable and affordable source of energy. Waste management is another area where BioCNG can have a positive social impact, diverting organic waste from landfills and diminishing health risks linked to landfilling practices. Agriculture can also benefit from BioCNG technology. BioCNG plants produce digestate, a by-product containing valuable nutrients that can serve as a fertilizer to foster soil health and enhance crop yields, contributing to sustainable agriculture and reducing reliance on chemical fertilizers.

While the report is optimistic about the cleaner and more sustainable future BioCNG promises, it acknowledges that widespread implementation faces challenges. Sustainable BioCNG production depends on a constant supply of feedstock from agricultural residues and organic waste. However, availability may be seasonal or irregular, introducing uncertainty to continuous BioCNG project operation. The report also notes the financial challenges of starting up BioCNG projects. Acquiring sizable upfront capital can be a formidable barrier. Also, potential investors may be wary of the risks BioCNG projects face, such as feedstock sources, technology uncertainties, market demand, and regulatory compliance.

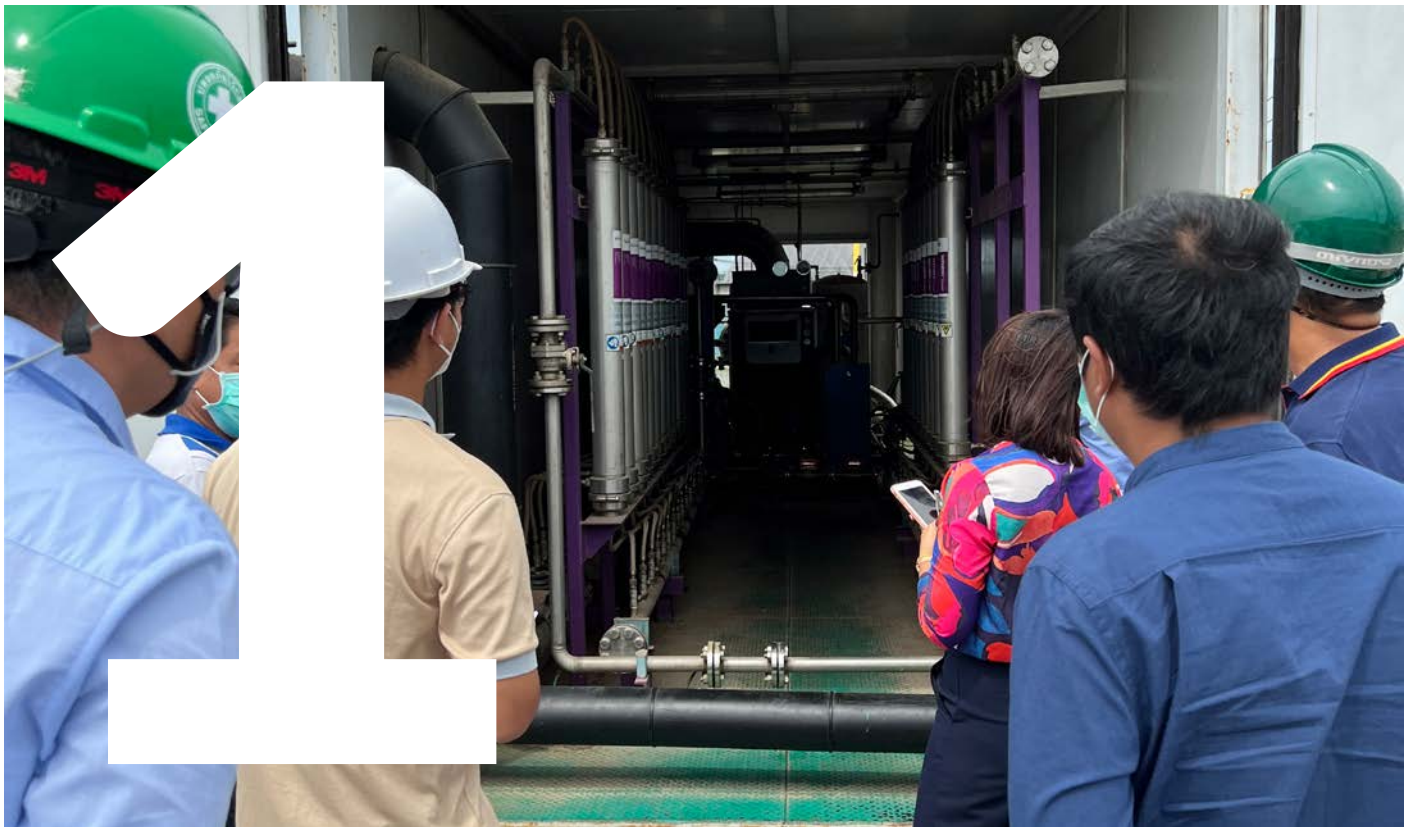
Infrastructure and interoperability issues present further challenges. Integrating BioCNG with existing gas distribution and transportation systems requires careful consideration. Achieving compatibility and fostering coordination with stakeholders involved in gas distribution and transportation are vital. BioCNG operators also face hurdles related to product offtake and demand. In regions where lower-priced fossil fuel substitutes already exist, demand for BioCNG as a transportation fuel or energy source may be limited. The absence of robust regulatory frameworks and policies represents yet another challenge. A lack of official guidelines and laws can limit BioCNG's adoption due to concerns regarding standards, quality, cost, and access.

GGGI acknowledges these are significant challenges. But they are not insurmountable. The report provides a range of recommendations for overcoming them.The report emphasizes developing a systematic method to identify and prioritize viable BioCNG projects. This involves mapping biomass resources strategically and ensuring a focused approach to projects with high potential for success.

To enhance BioCNG's competitiveness, government interventions like price guarantees could ensure long-term price stability and reduce project risk. The report also suggests exploring innovative business models to improve the overall resilience and profitability of BioCNG initiatives, highlighting successful approaches in other countries.

To attract investment, the report suggests implementing financial instruments. Strategies like interest rate subventions, risk guarantees, and other mechanisms can mitigate financial risks for investors.

The report underscores the pivotal role of policy and regulatory frameworks. It recommends creating or revising regulations, developing standardized business classifications, and defining national standards for BioCNG. While GGGI produced this report as a resource for its Country Teams, it is also intended for policymakers, investors, and other stakeholders interested in promoting BioCNG sector development. GGGI hopes the report's practical recommendations and case studies will help overcome challenges facing the sector and foster its growth. Ultimately, GGGI hopes this report will help create a more sustainable and resilient energy system, benefiting the environment, global prosperity, and humanity.



1. Introduction

1.1 Energy Security and Circular Economy

The dynamically evolving global energy landscape, coupled with changing geo-politics and the escalating impacts of climate change, underscores the risks inherent in existing energy systems and emphasizes the critical importance of energy security to our economies and societies. Despite the abundant renewable energy potential dispersed globally, around 80% of the global population resides in countries that are net energy importers.

Addressing these challenges requires adopting, accelerating and scaling-up energy transition solutions at the national level if the world is to ensure long-term energy security, price stability and national resilience.

Utilizing distributed organic wastes to produce biofuels, including biogas and organic manure[1] has multisectoral impacts and benefits. These include reducing our reliance on fossil fuels, mitigating methane greenhouse gas emissions that cause global warming, providing a less carbon-intensive fuel and providing an eco-friendly solution to waste management. Moreover, the socio-economic benefits of biofuels contribute to a just transition to a sustainable economy that fosters social equity, provides jobs, and strengthens communities. Significantly, reintroducing organic wastes into the value chain to produce biogas and organic manure promotes resource efficiency and transforms the linear waste economy into a circular bioeconomy.

This report draws from the experiences and lessons learned from the Global Green Growth Institute's (GGGI) BioCNG Global Program, initially funded by the Government of Denmark. Tailored to the unique contexts of India, Indonesia, and Thailand, the program reflects GGGI's conviction that BioCNG has significant potential for achieving energy security and clean energy transition in many GGGI member countries. Realizing this potential requires addressing policy and regulatory issues and developing viable business models for replication and scale-up.

Designed to provide GGGI Country Teams and other stakeholders with vital insights, the report examines effective biogas and BioCNG programs and projects. It reviews best practices, business models, case studies and lessons learned in developing BioCNG's production and application potential. The report also offers policy recommendations for promoting the development of the BioCNG sector.

The report is divided into several sections that study the emerging industry from various perspectives. It begins with an introduction

1 Organic manure is natural fertilizer made from decomposed organic materials like plant and animal waste. It improves soil quality and provides essential nutrients for plants, offering a sustainable alternative to synthetic fertilizers.

to the topic of biogas and BioCNG and its role in addressing the challenges of climate change, air pollution, and resource scarcity. The report then delves into the best practices for producing and using BioCNG and includes case studies from various industries and countries, including India, Indonesia, and Thailand. These case studies demonstrate the potential of BioCNG technology and highlight the different business models, financing mechanisms, and regulatory frameworks used for BioCNG projects. The report also emphasizes the economic, environmental, and social benefits of BioCNG, including its potential to reduce greenhouse gas emissions, create jobs, and promote rural development. Finally, the report offers policy recommendations for promoting the development of the BioCNG sector.

1.2 Introduction to Biogas, BioCNG, and BioLNG

Biogas production is a natural degradation of organic biomass in the absence of oxygen, known as "anaerobic digestion". The organic biomass includes agriculture residue, fruits and vegetable waste, cattle dung, sugarcane press mud, municipal solid waste, and sewage treatment plant waste, among others. Biogas production at a commercial scale is conducted in a gas-sealed unit known as a "Biogas Digester". Biogas is a gas mixture of mostly methane and carbon dioxide, along with water, oxygen, and other trace gases.

BioCNG or compressed biogas is produced from biogas through the process of desulfurization, upgrading, and compression. Biogas is first desulfurized, compressed and packaged in a cylinder or pumped into a natural gas grid. BioCNG has a composition and calorific value similar to natural gas or fossil fuel derived Compressed Natural Gas (CNG). BioCNG has a 92–98% methane content compared to biogas, which comprises 55–65% methane and 35–45% carbon dioxide. BioCNG is ideal for automobiles, as an industrial fuel and in power plants as a replacement for natural gas due to its high methane concentration, calorific value, and low impurity.

Liquefied Natural Gas (LNG) is obtained from CNG by cooling it down to a temperature of -161 to -164°C. One of its advantages is its significantly reduced volume compared to gaseous natural gas. The volume of 1 kg of LNG is only 1/600th of that of 1 kg of CNG, while the energy content of 1 liter of LNG corresponds to 3 liters of CNG. These positive characteristics make it easier to transport and store. LNG obtained from biogas is called liquefied biogas (LBG) or BioLNG. LBG is chemically equivalent to LNG.

As BioCNG and BioLNG/LBG are fuels derived from renewable biomass, CO_2 emissions from burning the fuel can be considered zero. BioCNG and BioLNG are produced from locally available waste. They can replace the fossil fuel derived natural gas that many developing countries import. BioCNG/BioLNG is an important fuel for energy security and clean energy transition and promotes a circular economy. Besides providing clean energy, the BioCNG/BioLNG process generates degraded biomass, a by-product that is very useful as a nutrient-rich fertilizer in organic agriculture.

1.3 Environmental and Social Safeguards in BioCNG projects

The large-scale BioCNG projects hold significant promise with clean energy transition and mitigation of environmental concerns by harnessing organic wastes and renewable resources. BioCNG or Biogas production relies on organic matters, such as agricultural residues, cattle dung, and food waste, among others. Therefore, effective waste management practices are imperative to manage the waste and prevent overexploitation and depletion sustainably.

Safeguarding the environment requires comprehensive environmental impact assessments during the initial stages of the project preparation. These assessments should analyze the potential effects on local ecosystems, soil quality, water sources, and air quality, among other factors. Understanding these impacts allows the development of mitigation strategies.

Government agencies and regulatory bodies are crucial for implementing stringent policies, standards, monitoring mechanisms, and ensure compliance with environmental protection measures. Further, community engagement and stakeholder participation are integral to successful environmental safeguards. Involving local communities fosters understanding, cooperation, and the adoption of best practices, ensuring sustainable development in harmony with nature and community.

1.4 Global Demand for Natural Gas

Globally, countries import 516.2 billion cubic meters (bcm) of LNG. The Asia-Pacific region accounts for 72% of this volume, and Europe 21%. Major trade movements for LNG in 2021 are shown in Figure 1 on the following page.

According to the International Energy Agency's (IEA) Gas market report, China, Japan, and South Korea are the Asia-Pacific's major importers. Demand for natural gas will likely remain resilient for at least the next decade in emerging markets and developing economies in Asia, such as Indonesia, Myanmar, Vietnam, the Philippines, Thailand, and India. Although the demand trajectory path in these countries will vary, it is expected all emerging gas markets in Asia will peak before 2040 as per the IEA's Announced Pledges Scenario (APS). In the long-term, demand for natural gas will decrease, reflecting the recent net-zero emissions pledges announced in several major growth markets in Asia, including China, India, Malaysia, Singapore, Thailand and Vietnam.

Scaling up biogas/biomethane is a core strategy for filling the natural gas demand-import gap and achieving clean energy transition.

While Africa has been a net LNG exporter for a long time, only a few African countries are presently exporting LNG. Africa is likely to have one of the highest growth rates in natural gas demand. North and West Africa, including Morocco, Senegal, Togo, and Cote D'Ivoire, account for over 90% of Africa's marketed production of natural gas. These countries produce natural gas to meet domestic demand. In contrast, Mozambique in Southern Africa exports a significant proportion of its large natural gas reserve. Morocco not only produces natural gas but also imports it and is potentially one of the largest natural gas markets in Africa. Morocco's domestic gas price is USD 6.5 per MMBtu, the highest across Africa. Meanwhile, the development of natural gas import projects in Africa is challenging, with project developers facing uncertainties regarding natural gas prices and a lack of financing for infrastructure development.[2,3]

South American economies have long been distant from the natural gas markets, primarily focused on self-sufficiency and regional integration. In the northern areas of Latin America, Mexico is increasingly integrated with the United States' natural gas market. However, it remains highly dependent on the US for gas imports. As the region's economy and population grow, so does the demand for natural gas, mainly driven by the replacement of coal in power generation and industrial processes. Colombia depends on natural gas imports, whereas Peru is likely to remain a natural gas exporter. Ecuador is an oil producer, which provides for 83% of the country's energy supply and thus not a natural gas market. Paraguay's energy mainly comes from hydropower (54%) and biofuels and waste (26%).[4,5]

1.5 Global Fertilizer Demand/Import

Global demand for inorganic fertilizers, expressed as the sum of nitrogen, phosphorus, and potassium, was 201 million tonnes in 2020. Nitrogen constitutes more than 50% (113 million tonnes) of the global demand. The remaining demand consists of 24% for phosphorous (48 million tonnes) and 20% for potassium (39 million tonnes).

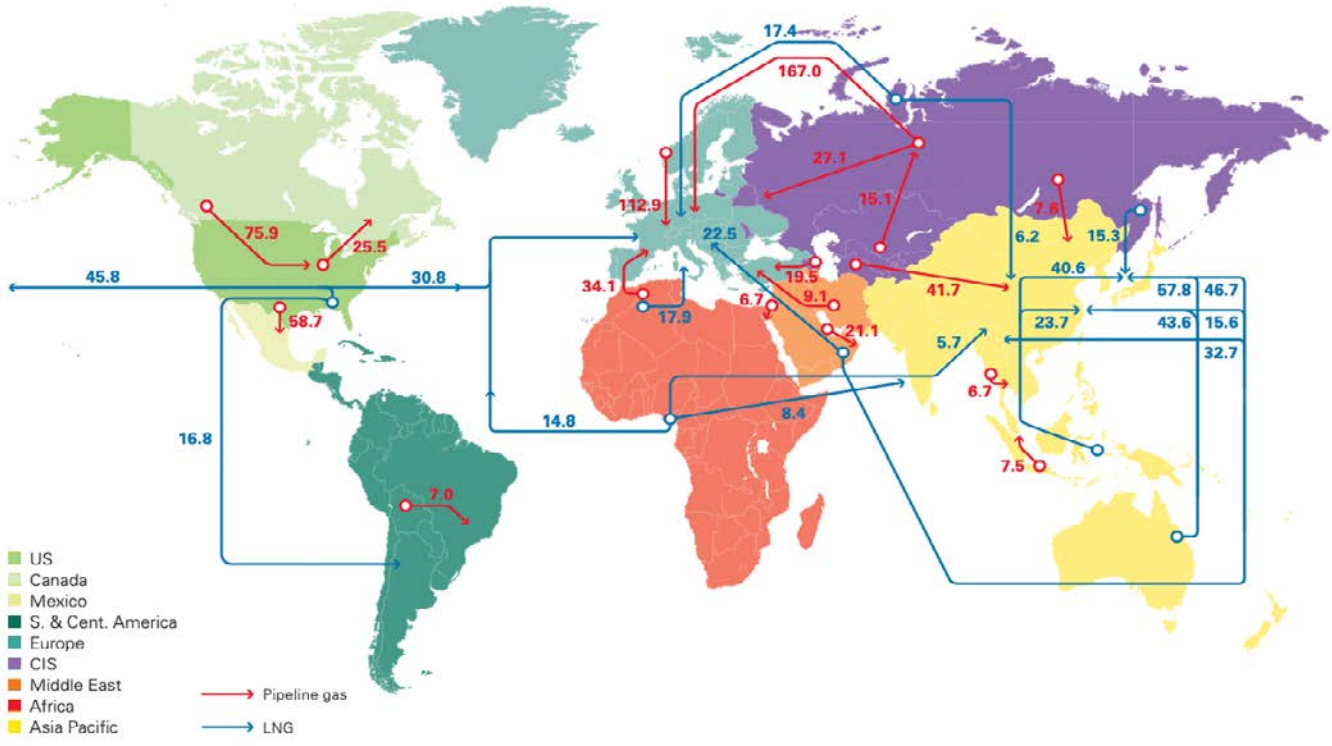
2 Africa's LNG import prospects in an era of high volatility and uncertainties, The Oxford Institute of Energy Studies, June 2022

3 Natural Gas in the African Energy Landscape, African Energy Commission, AFREC Policy Brief 2, July 2021

4 South American Gas Market and the role of LNG, The Oxford Institute of Energy Studies, October 2016

5 Gas resources in Latin America: the challenges to development, Wood Mackenzie

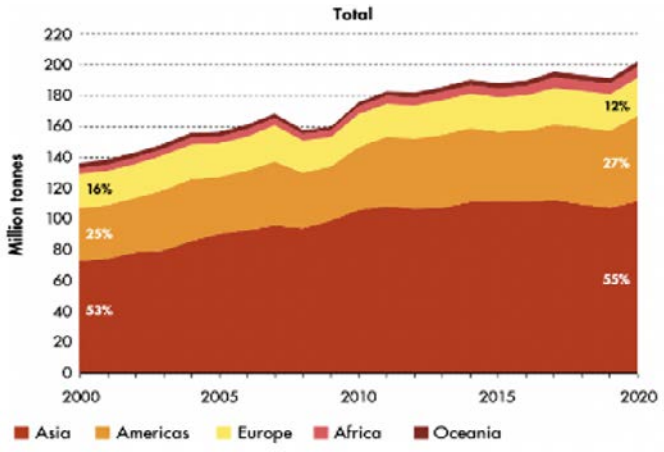
Figure 1. Major trade movements for LNG in 2021, trade flows worldwide (billion cubic meters)



Source: BP Statistical Review of World Energy 2022

Asia represented 55% of the world's total agricultural use of inorganic fertilizers in the year 2020. Central and South America imports 100% of its urea consumption. In comparison, 50% of the urea consumed in Africa is imported.[6] The global demand for fertilizer is shown in Figure 2.

Figure 2. Global fertilizer demand

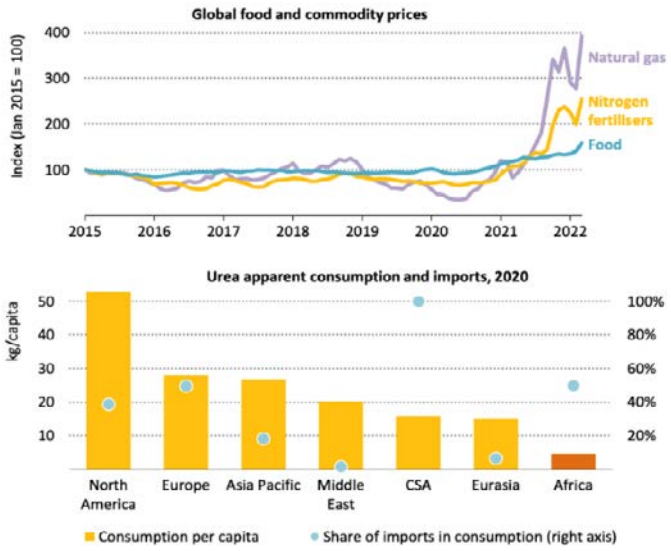


Source: FAO

Global increases in natural gas prices cascade to fertilizers and then to food prices. Africa has the lowest fertilizer use, applying only 20 kg per hectare. Despite this, Africa has significant exposure to global price volatility of food commodities and fertilizer, as it is highly dependent on imports. As per the United Nations Food and Agriculture Organization (FAO), Africa has imported more than 30% of its demand for cereals, while in North Africa the share is more than 50%. Urea accounts for around 60% of mineral nitrogen-based fertilizer consumption in Africa. However, about half of this demand is met through imported urea. Morocco, Cote D'Ivoire, Ecuador, and Ethiopia are among the major fertilizer import markets in Africa.[7] Colombia and Paraguay depend on imported (including raw materials) for fertilizer to meet domestic demand. Asian countries importing urea include Indonesia, India, Thailand, Malaysia and Vietnam.

The demand for inorganic fertilizer and resulting import for food production can be met by the earlier-mentioned organic manure by-product that comes from producing BioCNG. There is a clear correlation between regions with a high potential for BioCNG production and demand for fertilizer. For more information about global food and commodity prices and area imports, refer to Figure 3 below.

Figure 3. Global food and commodity prices and urea imports and consumption by region, 2015-22



Source: FAO

6 Africa Energy Outlook 2022, IEA

7 Africa Fertilizer Market Development, Gulf Petrochemicals and Chemicals Association

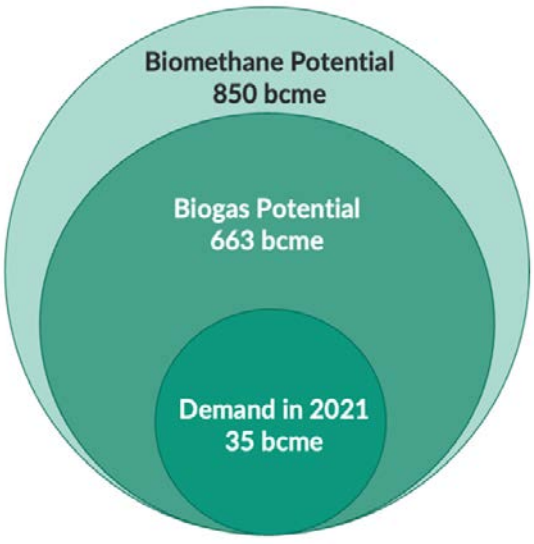
2. Potential for BioCNG

Bioenergy is already an important energy source globally, contributing 9% of global energy demand, with 55 exajoules (EJ) in 2019. The International Renewable Energy Agency's (IRENA) 1.5°C scenario estimates that bioenergy will represent 25% of the total primary energy supply by 2050, with 153 EJ, and will play an important role in achieving the Paris Agreement's net-zero goal. [8]

The world generates a large volume of organic matter (biomass), presenting a major environmental, health and development challenge. Further, the inappropriate management, conversion or treatment of biomass contributes significant levels of global greenhouse gas (GHG) emissions. The IEA's 2022 Outlook for Biogas and Biomethane has estimated a biomethane[9] potential of 850 billion cubic meter equivalent (bcme), as shown in Figure 4. Only a fraction of the estimated biomethane potential is realized today. However, the full realization has the potential to cover 20% of global gas demand. [9]

The current biogas demand for 35 bcme is estimated to reach more than 400 bcme by 2050 in a net-zero scenario.[10] Currently, over 60% of biogas production capacity lies in Europe and North America. However, a large opportunity lies in the Asia-Pacific and Central and South America regions, with a combined 50% of global estimated potential.

Figure 4. Global biogas and biomethane demand in 2021 and the estimated sustainable potential



Source: IEA

8 World Energy Transition Outlook 2022, International Renewable Energy Agency

9 Biomethane can be produced using biomass gasification and upgrading biogas (anerobic digestion). Around 90 % of the Biomethane comes from upgrading biogas.

10 World Energy Outlook, 2022, IEA

A wide variety of biomass can be used to produce biogas and fermented organic manure (FOM). Agriculture residues, cattle and bird manure, fruit and vegetable waste, organic municipal solid waste, wastewater sludge and industrial waste such as press mud from sugar cane, among others, can be used in different mixes of feedstocks to maintain optimal digestion conditions and maximize biogas production.

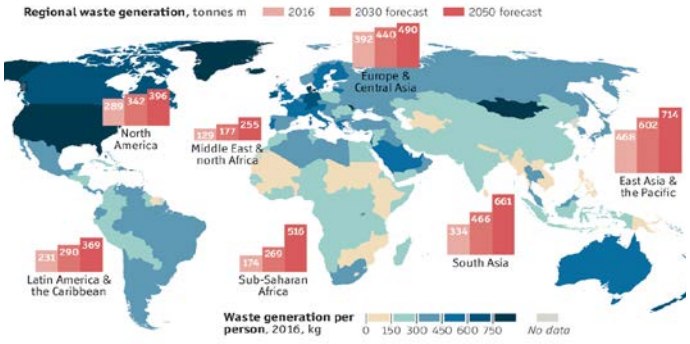
2.1 Food and Green Waste

Urbanization has increased in speed and scale in recent decades. Rapid urban population growth has resulted in several land use and infrastructural challenges, including solid waste management.

According to the World Bank, the global generation of solid waste was estimated at 2.24 billion tonnes in 2020 and is expected to increase by 73% to 3.88 billion tonnes in 2050.[11] The World Bank also estimates that 1.6 billion tonnes of carbon dioxide (CO2) equivalent GHGs were generated from solid waste management in 2016, which is equal to 5% of global emissions. Around 50% of these emissions were from food waste. Without improvements in the sector, solid waste related emissions are expected to increase to 2.6 billion tonnes of CO2 equivalent by 2050.[12] The FAO estimates that global food loss and waste generate 4.4 billion tonnes of CO2 equivalent annually, or about 8% of total anthropogenic GHG emissions.[13]

The East Asia-Pacific region and South Asia generates most of the world's waste. The composition of municipal solid waste (MSW) differs across income levels. For instance, high-income countries generate relatively less food and green waste, at 32% of total waste. In contrast, middle- and low-income countries generate more than 50% of food and green waste. All regions generate about 50% or more organic waste, on average, except for Europe, Central Asia and North America, which generate higher portions of dry waste.[14] Figure 5 shows the regional distribution of the current waste generation and the 2030/2050 forecast.[15]

Figure 5. Regional distribution of current waste generation and 2030-2050 forecast.



Some of the countries in Latin America and the Caribbean have a "kilogram per capita per day" waste generation rate higher than the global average of 0.74, including Mexico (1.16), Ecuador (0.89) and Costa Rica (0.86), among others. Mongolia (2.62) and Thailand (1.08) have significantly higher waste generation rates in East Asia and the Pacific. In the Middle East and North Africa, the United Arab Emirates (1.6) and Qatar (1.27) have high waste generation rates. The countries with the highest waste generation are Rwanda (1.01) in Sub-Saharan Africa and India (0.57) in South Asia. These GGGI member/partner countries have great potential to demonstrate and replicate waste to BioCNG and FOM solutions and catalyze investments for green and resilient infrastructure for efficient waste management.

2.2 Agriculture Residues

The total crop residue production in the world is estimated at 4 billion tonnes (dry matter) per year. The Intergovernmental Panel on Climate Change (IPCC) estimates the energy production potential from agricultural residues is between 15 and 70 Exajoule (EJ) per year. At the regional level, North America, South America, Eastern Asia, and Southern Asia each produce more than 500 million tonnes of agriculture residue. Figure 6 shows the date for the geographical distribution of residue output from barley, maize, paddy, soybean, sugar cane and wheat production.[16]

11 https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management

12 https://openknowledge.worldbank.org/entities/publication/d3f9d45e-115f-559b-b14f-28552410e90a

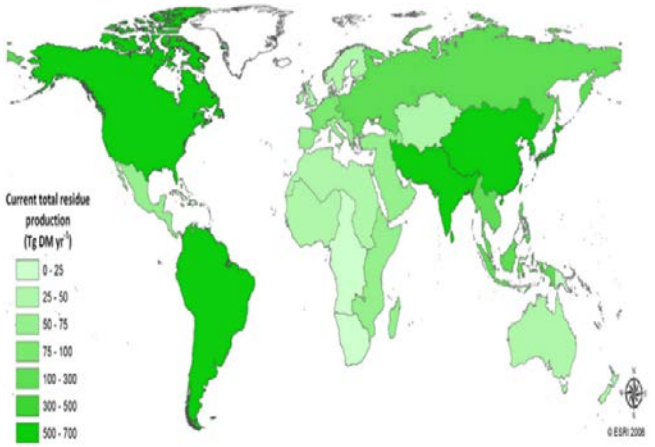
13 https://www.fao.org/3/bb144e/bb144e.pdf

14 https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html

15 https://www.economist.com/graphic-detail/2018/10/02/global-waste-generation-will-nearly-double-by-2050

16 N.S. Bentsen et al. - Progress in Energy and Combustion Science 40 (2014) 59- http://dx.doi.org/10.1016/j.pecs.2013.09.003

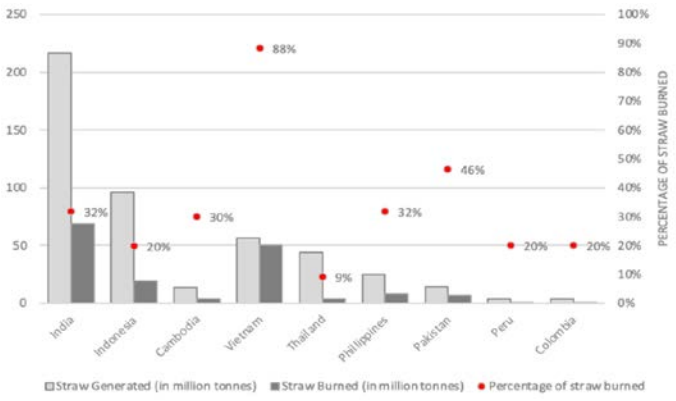
Figure 6. Geographical distribution of estimated production of agriculture residues



Source: Journal - Progress in Science and Combustion Science

Open burning of paddy straw is a common practice across the globe. However, recent research suggests that in Asia, which accounts for more than 70% of the world's rice and straw production, a large volume of agricultural residue is burned in uncontrolled environments in countries like China, India, Vietnam, and Indonesia.[17] Figure 7 presents a comparison of rice straw burning among GGGI member countries.

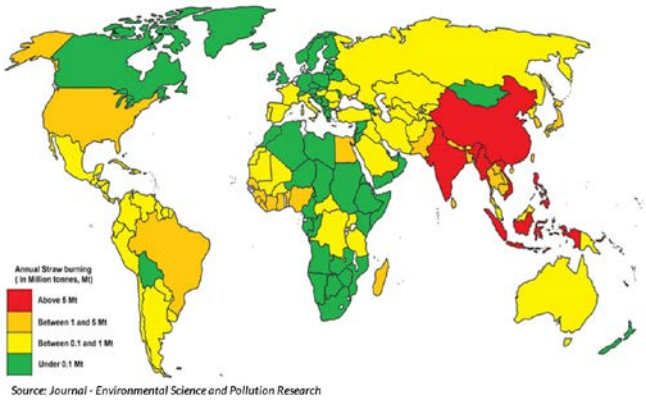
Figure 7. Rice straw burning comparison among GGGI member countries



Source: Journal - Environmental Science and Pollution Research

China is among the leading producers of food grains in the world and produces 700 million tonnes of waste straw from different crops. India is the second largest agriculture-based economy and generates 500 Mt of agricultural residues annually– out of which 92 MT is openly burned every year. Indonesia, the world's third largest producer of rice, burns 19.3 MT of rice straw annually. In Vietnam, until 2014, 98% of leftover rice straw was burned. Besides these major rice-producing countries, other Asian countries like Thailand, Myanmar, Philippines, Japan, Pakistan, Korea and Sri Lanka also produce considerable quantities of rice accompanied by large-scale burning of the waste straw. Figure 8 presents the volume of paddy straw generated and burned each year globally and clearly shows the high levels occurring in Asia's major and emerging economies. GGGI member and partner countries, and particularly the intense rice straw burning countries of India, Indonesia, the Philippines, Thailand, Vietnam, and others, have great potential to turn this challenge into an opportunity using BioCNG technology.

Figure 8. Mapping of the global rice straw burning zones.



Source: Journal - Environmental Science and Pollution Research

17 Gurraj et al., Rice straw burning: a review on its global prevalence and the sustainable alternatives for its effective mitigation, Environmental Science and Pollution Research, 2021, https://doi.org/10.1007/s11356-021-14163-3

3. Biomass-to-BioCNG Conversion Process and Technology

Biogas is produced through a process called anaerobic digestion. During the process, organic matter decomposes in the presence of methane-producing bacteria or methanogenic bacteria in an oxygen-free environment. The biogas is further enriched to increase the methane content and meet the application requirements in the transport, industry, domestic and commercial sectors. As highlighted in Figure 9 and Figure 10, the typical Biomass-to-Biogas value chain represents the entire process flow from the collection of feedstocks to the final utilization of biogas (enriched biogas) and FOM. The Biomass-to-Biogas process includes pre-treatment, anaerobic digestion in a reactor/digestor, upgradation and purification, instrumentation and automation, and storage and distribution. Brief details about the process are provided following figures 9 and 10.

a. Feedstock Collection, Storage and Preparation

Organic waste is collected from various sources, such as agricultural residues, industrial organic waste, food and vegetables, cattle dung and sewage sludge, among others. Intermediate storage that minimizes degradation in ambient conditions is used to ensure biomass availability, continuous supply and process sustainability. Feedstock such as agriculture residues are stored and dried in large quantities for months. Industrial organic wastes such as press mud can also be stored for months. Innovative measures such as layering inert materials and covering them with sheds limit the degradation of the waste. Food and vegetables, cattle dung, and sewage sludge are wet wastes and should be used the day they are collected or stored for only one or two days.

Figure 9. Schematic diagram for a bio-mass to biogas conversion plant

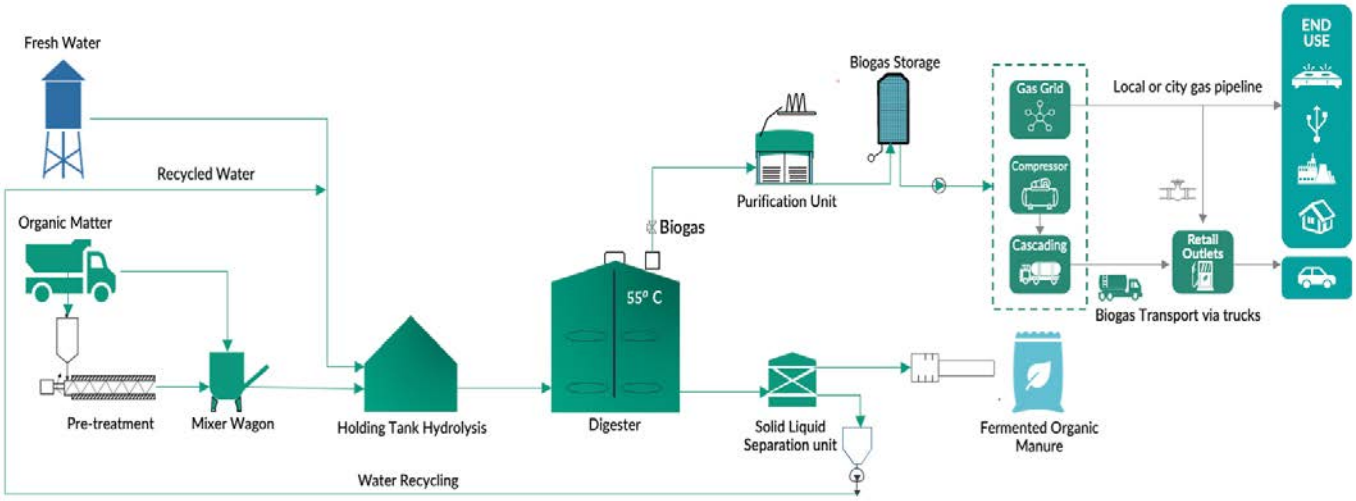
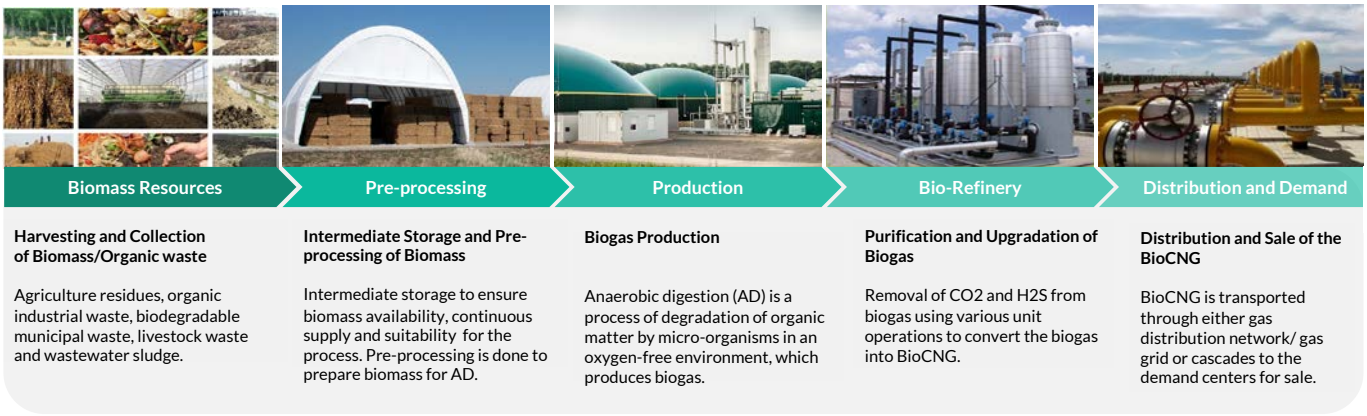


Figure 10. Biomass to biogas process and supply chart



b. Pre-treatment

Feedstocks such as agriculture residues must be prepared for feeding. Preparation can include shredding, chopping, or grinding to increase their surface area, improve the digestibility of their organic matter and enhance biogas production. Pre-treatment methods include physical, mechanical, thermal, chemical, biological or a combination of these and other methods.

Physical separation, such as screening and sieving, segregate the organic and inorganic MSW. Chopping, grinding, and milling are mechanical approaches to reducing the size of agricultural residues. Thermal methods, such as steam explosion, and the use of chemicals, such as acids, treat agricultural residues, separating the lignin from the waste and improving its digestibility.

c. Anaerobic Digestion

Anaerobic digestion is a process of degradation of organic matter by micro-organisms in an oxygen-free environment, which produces biogas. Factors, including temperature, moisture and nutrient contents, retention time and pH, are also critical for the AD's success. AD best occurs at two temperature ranges: the mesophilic (30-40°C) and thermophilic (50-60°C). During the process, acid-producing bacteria breakdown the organic matter into volatile acids before the anaerobic methanogenic bacteria convert them into biogas. Industrial scale digesters include continuously stirred tank reactors, plug-flow reactors, anaerobic sequencing batch reactors, Upflow Anaerobic Sludge Blankets (UASB), or other specialized designs. Table 1 highlights the suitability of the type of anaerobic digester based on the total solid percentage and climatic conditions.[18]

18 Gurraj et al., Rice straw burning: a review on its global prevalence and the sustainable alternatives for its effective mitigation, Environmental Science and Pollution Research, 2021, https://doi.org/10.1007/s11356-021-14163-3

Table 1. Type of anaerobic digester based on suitability parameters

Sl. No.	Type of Anaerobic Digester	Suitability Parameters				
		Technology Level	Total Solid - TS in feedstock (in %)	Hydraulic Retention Time (in Days)	Climatic Condition	Co-digestion of Feedstock
1.	Covered Anaerobic Lagoon Digester	Low	0.5 to 5	30 to 60	Temperate and warm climates	Not Optimal
2.	Plug-flow Digesters	Low	12 to 15	20	All climates	Not Optimal
3.	Continuously Stirred Tank Reactors	Medium	3 to 10	15	All climates	Optimal
4.	Upflow Anaerobic Sludge Blanket (UASB)	High	<3	5	All climates	Optimal
5.	Induced Blanket Reactor (IBR)	High	6 to 12	5	All climates	Optimal
6.	Fixed Film Digester	Medium	1 to 5	5	All climates	Optimal
7.	Anaerobic Sequencing Batch Reactor	High	2.5 to 8	5	All climates	Optimal
8.	High Solids Anaerobic Digestion (HSAD) or Dry Fermentation	Low	>25	20-30	All climates	Optimal

d. Advanced Instrumentation and Automation

At an industrial scale, continuous monitoring and control systems are important for optimizing the biogas production process and other plant operations. Monitoring such parameters as temperature, pH level, feedstock loading rates, and gas composition is important for ensuring stable, efficient, and enriched biogas production.

e. Biogas Purification and Enrichment

Removal of CO2 and H2S from biogas needs to be done to improve the quality (calorific value) of the biogas for different applications. Hydrogen sulfide (H2S) is an impurity in biogas. It can be removed using biological fixation, iron chloride dosing, water scrubbing, activated carbon, iron oxide, and sodium hydroxide, to name a few. Scrubbing, chemical absorption, pressure swing adsorption (PSA), membrane purification, and cryogenic separation are some of the technologies used for absorption, adsorption, and membrane separation for removing CO2 from the biogas. Membrane separation is a new technology where dry membranes for biogas upgrading are made of materials permeable to carbon dioxide, water and ammonia. Hydrogen sulfide, and oxygen permeate through the membrane to some extent, while nitrogen and methane only pass to a very low extent. Tables 2 and 3 provide a comparative analysis of technologies to remove hydrogen sulfide (H2S) and carbon dioxide (CO2). The technical specifications for using BioCNG in industrial scenarios are available in Appendix I.

Table 2. Comparative analysis of technologies to remove hydrogen sulfide (H2S)

Sl. No.	Technology/Method	Parameters			
		Efficiency	Capital Cost	O&M requirement	Complexity
1.	Biological Fixation	Moderate	Moderate	Low	Moderate
2.	Iron Chloride Dosing	Moderate	Low	Moderate	Low
3.	Water Scrubbing	High	High	Moderate	High
4.	Activated Carbon	High	High	Moderate	Moderate
5.	Iron Hydroxide or Oxide	High	Moderate	Moderate	Moderate
6.	Sodium Hydroxide	High	Moderate	High	Moderate

Table 3. Comparative analysis of technologies to remove carbon dioxide

Sl. No.	Technology/Method	Requirements/Performance				
		Pre- H2S removal required	Working Pressure (bar)	Methane Loss	Methane content in Enriched biogas	Electricity Consumption (kWh/m3)
1.	Pressure Swing Adsorption	Yes	4 to 7	20 to 30%	>96%	0.25
2.	Water Scrubbing	No	4 to 7	5 to 10%	>97%	<0.25
3.	Mono-ethylamine system	Yes	No Pressure	<0.1%	>99%	<0.15

f. Biogas Storage and Distribution

Portable storage cylinders, also known as "cascades", are used to collect and store biogas at high pressure (more than 200 bar). Next, the cascades are transported to distant locations where the biogas is decompressed and distributed locally. Integrating biogas with existing local or city gas distribution grids or pipelines is also possible, subject to technical suitability and at a relatively low pressure of 6 to 15 bar. This integration allows the distribution and use of biogas alongside natural gas in the existing infrastructure.

g. Fermented Organic Manure Management

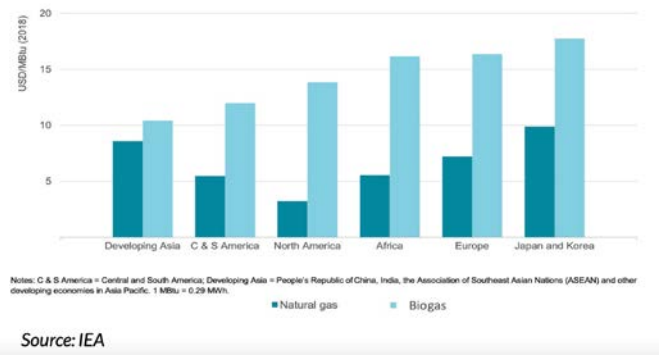
The FOM left after anaerobic digestion contains valuable nutrients and organic matter. It can be further processed and utilized as a high-quality organic fertilizer or soil conditioner. The FOM produced from the BioCNG plant can also be enriched to produce value-added organic fertilizers such as organic phosphate fertilizers, organic potash fertilizer, organic silica fertilizer, organic sulfur fertilizer, organic micronutrient fertilizer, and carbon-rich organic manure, to replace its chemical counterparts effectively.

4. Key Challenges and Gaps

4.1 Lack of Policy and Regulatory Framework

The higher cost of producing biogas compared to natural gas impedes the demand for biogas. Developing Asia is the only region where the cost gap between natural gas and biogas is minimal. Figure 11 summarizes the average cost of biogas production in other regions, excluding feedstock costs. Further, biogas competes with natural gas in the open market, where natural gas prices are subsidized. This creates an uneven playing field for the biogas sector. An absence of supportive policies and regulations specific to the biogas and BioCNG sectors can be a significant barrier. Inadequate incentives, tariffs, and feed-in tariffs for BioCNG can hinder project viability and financial attractiveness. Policies and regulations related to blending mandates, tax incentives and infrastructure development are crucial in promoting the BioCNG sector's growth.

Figure 11. Average cost of biogas production in other regions, excluding feedstock cost



Source: IEA

4.2 Supply-Side Challenges

a. Variations in Feedstock Availability, Affordability, and Quality

Consistent and reliable feedstock supply, such as organic waste or agricultural residues, is crucial for the sustainable operation of BioCNG production facilities. The availability and quality of feedstock, such as agricultural residues and organic waste, can vary seasonally and regionally. Adequate feedstock management and logistics are essential to maintain continuous BioCNG production. Further, feedstock/biomass price volatility due to seasonality, supply-demand dynamics and market conditions also poses a challenge for BioCNG projects. These price fluctuations can undermine a BioCNG project's economic viability.

b. Limited access to capital and lack of ecosystem for project-based financing

Many factors make funding large-scale BioCNG projects challenging. These factors include substantial upfront capital investment and perceived investment risks due to factors such as feedstock availability, technology uncertainties, market demand, and regulatory compliance. These factors also include an absence of standardized contracts, uncertainty regarding the revenue streams, limited knowledge of the BioCNG sector among financial institutions and a subsequent lack of relevant financial instruments.

4.3 Technology and Operational Challenges

a. High technical and Operational Complexity

Operating large-scale BioCNG plants demands a certain level of technical expertise and knowledge. Maintaining optimal anaerobic digestion conditions, managing process parameters, and handling potential issues like feedstock imbalances or process disruptions require skilled personnel and sophisticated monitoring systems. Factors such as retention time, temperature, pH, and mixing need careful control to maximize biogas yields and minimize process inefficiencies. The limited availability of skilled workforce with expertise in BioCNG technologies, operation, and maintenance makes the project developer and/or technology provider's role critical to minimizing downtime and optimizing system performance.

b. Lack of Technical and Design Standards

The existing BioCNG project framework lacks benchmarking, standards and specifications for various components and processes in BioCNG projects. These include anaerobic digestion, gas upgrading, compression, storage and transportation. Very few large-scale operational projects are developing these benchmarks to ensure consistency, interoperability, safety, and quality across different BioCNG projects.

4.4 Demand Side Challenges

a. Infrastructure and Interoperability

The availability of gas infrastructure and demand from end-users such as industries and transportation is crucial for a sustainable and efficient BioCNG production business model. One challenge is integrating BioCNG into existing gas distribution and transportation systems. The compatibility of BioCNG with existing infrastructure, such as gas pipelines and refueling stations, needs to be considered. Coordination and cooperation with stakeholders involved in gas distribution and transportation are crucial for seamless integration.

b. Product Offtake and Demand

The demand for BioCNG as a transportation fuel or energy source may be limited, especially in regions where alternative fossil fuels are readily available and cheaper. BioCNG projects typically require long-term offtake agreements or contracts along with a conducive market environment and support for higher offtake prices to provide revenue stability and attract financing. Also, the lack of regulatory frameworks for the use and application of FOM is limited due to challenges related to quality, cost, and access.

5. Developing an Impactful BioCNG Program

5.1 Approach to Impactful Program

As a best practice for developing a large-scale and impactful program for a sector such as BioCNG, implementing interventions in distinct phases is necessary, especially for countries at the nascent stages of development. It is important to have systematically structured phases to develop sectoral and geopolitical understanding, create enabling environments through interventions, prove viability, demonstrate templates for replication, and develop scale-up strategies to achieve broad impact. A typical program can be divided into three distinct phases: design, implementation and scale-up. Figure 12 illustrates the interventions and inter-linkages of these phases.

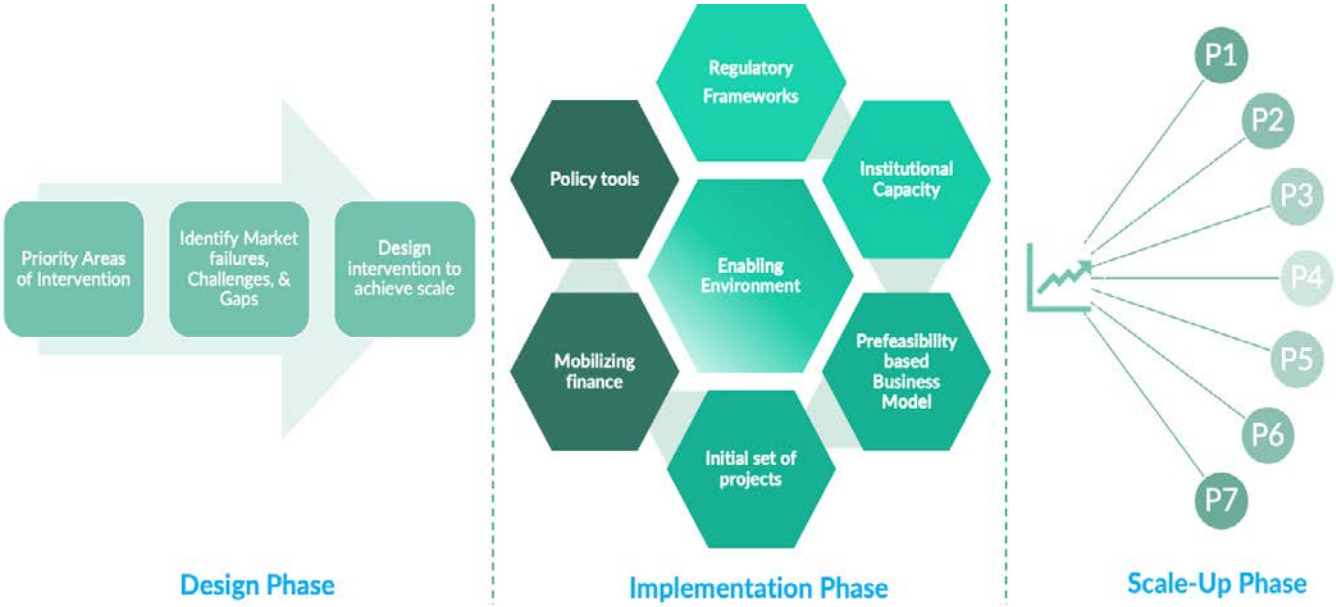
a. Design Phase

The program's design phase undertakes the foundational work and clearly understands market failure, challenges, gaps and opportunities. The design phase should define the program, undertake landscape analysis, develop strategic partnerships and design the intervention. The design phase generally includes a strategic partnership with nodal ministry, undertaken landscape analysis, engagement with stakeholders, and identification of gaps and barriers.

b. Implementation Phase

The implementation of the designed intervention phase focuses on creating an enabling environment for the proposed solution that recognizes such critical elements as policy, regulatory frameworks, institutional capacity, business models and access to finance. The phase often involves first developing a set of demonstration projects to influence policy or regulatory frameworks, benchmark technologies/performance, and reference projects to financial viability and investment potential. This is critical for developing a replication template. The implementation phase also provides an opportunity to gather data and develop mechanisms to mitigate the risks impeding accelerated uptake and scale-up. The implementation phase includes policy recommendation/advocacy to address the challenges, project assessment framework, suitable business model development, engagement with stakeholders, catalyzing investment to demonstrate replicable template.

Figure 12. Interventions and interlinkages of design, implementation, and scale-up phases



Source: GGGI

c. Scale-Up Phase

Once several model projects with appropriate policy and regulatory support are available to demonstrate the viability of the technology, the sector begins to attract investor interest. New projects can be conceptualized, designed and implemented using the templates, resulting in scaling up of the intervention. Concessional and innovative financing approaches can further accelerate replication projects and grow the sector. The scale-up phase may include developing project assessment framework to create a pipeline of projects and business models to catalyze investments from debt investors and private sector participation.

5.2 GGGI's Global Program on BioCNG

GGGI's BioCNG Global Program supports governments in target countries in developing a robust demand and supply BioCNG market ecosystem that includes service and technology providers. The program aims to create an enabling business environment for the BioCNG sector, reduce barriers to the recovery and use of BioCNG and support environmentally sustainable and commercially scalable business models adapted to local conditions. As explained in the previous sections, the BioCNG Program implements strategic interventions in distinct phases with specific activities. Figure 13 outlines the activities undertaken under various program phases. Section 5.3 provides details about the key activities.

5.3 BioCNG - Design Phase

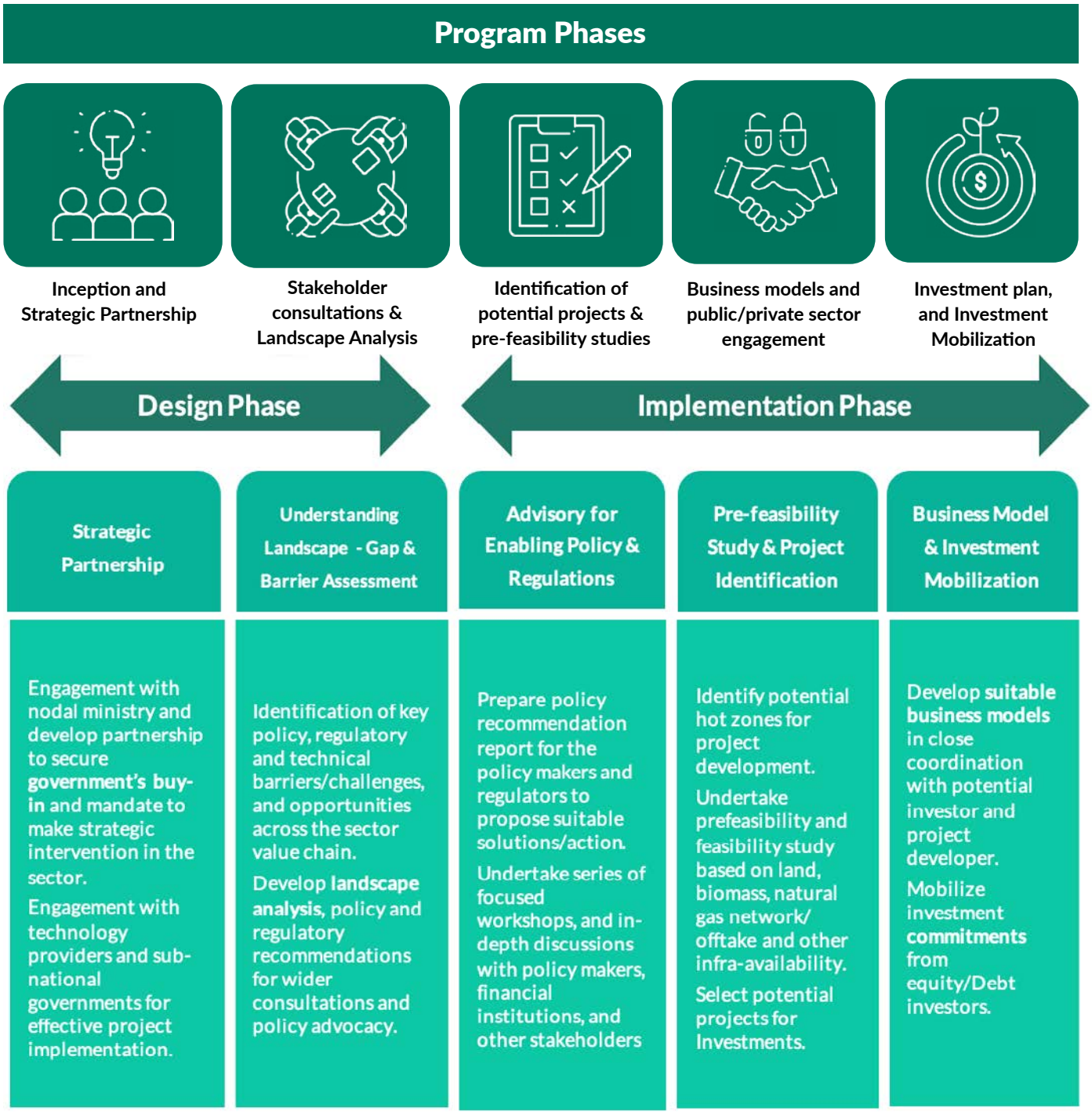
a. Strategic Partnership

Strategic partnerships play a crucial role in successfully developing and implementing challenging and impactful projects. They bring together stakeholders with complementary expertise, resources, and goals to create synergies and achieve shared objectives. The government plays a critical in creating an enabling policy and regulatory ecosystem and achieving replicability and scale-up. Hence, strong government commitment at the national and sub-national levels is imperative for effective implementation. Further, to engage market forces in promoting the sector, it is necessary to engage with technology providers, project developers, oil and gas marketing companies, fertilizer companies, and others.

b. Landscape Analysis – Gap and Barrier Analysis and Opportunities

Landscape analysis presents the "as-is" scenario of the sector and value chain, which involves a comprehensive assessment of the current state of technology adoption and utilization, identifying gaps, barriers, and opportunities to promote its further development and integration into the existing energy sector development pathway. A comprehensive landscape analysis provides policymakers, investors, technology providers and other stakeholders with valuable insights to make informed decisions and drive BioCNG as a sustainable energy option. Consulting with all key stakeholders is critical to ensuring a meaningful landscape analysis.

Figure 13. Activities undertaken in various phases of the program



5.4 BioCNG– Implementation Phase

a. Policy Recommendations

The report covers the BioCNG landscape in three countries and presents recommendations for each. The recommendations address sustainable biomass supply and resource sufficiency, suitable and innovative business models, appropriate BioCNG pricing, FOM, demand creation and project viability, and long-term sustainability mechanisms.

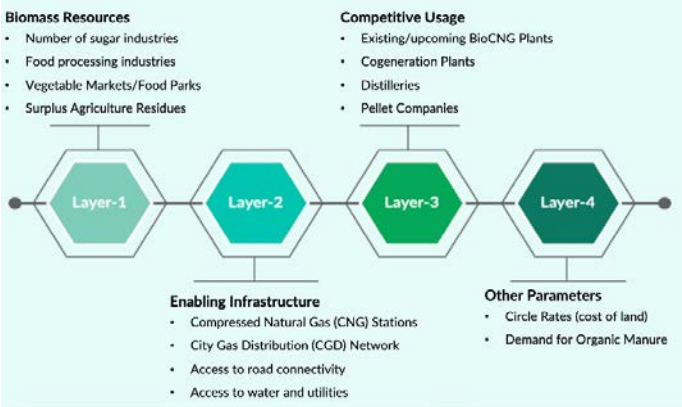
Further, an initial business model shall be prepared by undertaking market engagement to support the development of a scaled BioCNG market. All business models should be adjusted based on market feedback and evolving policy framework. Accelerated

adoption and replication at scale will require building awareness and understanding among financial institutions regarding the sector's opportunities, risks and returns. Multilateral banks and other development finance institutions should be engaged in the discourse at this stage.

b. Pre-feasibility, Project Identification and Feasibility Analysis

Carrying out a comprehensive pre-feasibility analysis based on resource, technical, financial, market and environmental aspects is crucial. It informs decisions regarding project selection, including their technical feasibility, financial viability and risks. One approach to this process is Identifying "hotzones", locations considered suitable for siting a BioCNG plant. Hotzones[19] are identified by assessing supply-side factors, such as the presence of biomass and supply chains, and demand side factors, such as management and offtake of BioCNG, FOM and Biogenic CO2. Figure 14 highlights the key parameters that can be considered for each layer of the assessment framework. Additionally, an assessment of technology suitability and financial viability provides project developers and investors with valuable information for making an investment decision.

Figure 14. Key parameters for project assessment



Source: GGGI

Biomass Resource - Feedstock

For greenfield BioCNG projects, the source and distribution of biomass resources within a specific geographic area is required to estimate potential and ensure biomass availability throughout the year. Biomass resources such as municipal organic waste, surplus agriculture residues, organic industrial waste, press mud, palm oil mill effluent, processed food waste and energy crops are some of the feedstock sources that supply BioCNG plants. The total biomass potential can be estimated using geographical information system (GIS) analytics, as explained in Box 1. However, the availability of this biomass varies across the year. For instance, surplus agriculture residues and press mud, etc., are only available seasonally and present significant storage and management demands. Municipal and animal wastes are generally available throughout the year but come with the inherent challenge of segregation, collection and transportation.

Box 1 - Resource Mapping using Geographic Information System tools:

Secondary data can be integrated and analyzed using GIS software, including locations and the estimated quantity of waste generated from the supply sources, such as industry, livestock farms and others. The potential from distributed biomass resources can be calculated based on a population's municipal waste and agriculture data, such as surplus residues. Further, heatmaps can be prepared to identify the potential of distributed biomass resources. GIS can also overlay datasets to create biomass resource maps.

A monthly feedstock supply matrix can be prepared considering multiple biomass sources (see the BioCNG plant operation matrix template in Appendix II). The plantation of energy crops, such as Napier grass, can play a crucial role in filling a gap in biomass supply due to the unavailability of waste as well as minimizing storage requirements for seasonal biomass. A diversified feedstock system – multiple feedstocks from different sources – is important in mitigating the biomass supply risks, creating a robust biomass resource supply chain, and ensuring continuous plant operation round-the-year.

Competitive Usage of Biomass

Biomass resources can be used in many industries. Resources such as paddy straw in the form of pellets or briquets are used along with coal in thermal power plants for co-firing. Mapping a region's operational thermal and biomass power plants and bio-compositing plants in the region is important to calculating competitive biomass usage, estimating the actual or surplus availability of biomass and finalizing the hotzone. Box 2, highlights some of the considerations for establishing a Biomass value-chain using Localized Storage Centres/Biomass Depots.

19 Hotzones are areas or clusters of 20-to-25-kilometre radius that are highly suitable for sustainable project due to their high technical potential and low risk.

Box 2 - Localized Storage Centres/Biomass Depots:

The seasonal availability of large amounts of biomass,, such as paddy straw is a major challenge for the environment and BioCNG projects. Limited capacity for the collection and storage of paddy straw during harvesting, coupled with the short time gap between harvesting and sowing of the next crop, often leads to the uncontrolled burning of paddy straw in fields. This contributes to GHG emissions and the loss of a valuable resource. While the biomass sector is rapidly maturing to create a market for meeting various energy needs sustainably and commercially, achieving scale for the biomass market necessitates logistic support. This support includes establishing storage, processing and transportation facilities for a sustainable biomass supply chain. Hence, organizing the value chain becomes imperative and requires creating a mechanism or a marketplace to match biomass demand and supply for BioCNG projects and other applications. An organized, such as biomass depots or banks at multiple locations serving as satellite facilities for biomass storage, processing and distribution, can play a pivotal role in addressing these challenges and fostering a more sustainable and efficient biomass ecosystem.

Enabling Infrastructure and Market

There are several important infrastructure enablers. These include a well-distributed road network, operational natural gas grids, an existing market and demand for plant products, and utility companies. All of these are necessary for effectively planning and implementing successful and sustainable BioCNG projects.

Access to Wider Road Network

The ease of transporting biomass from the source through a good road network is an important consideration in selecting the optimal plant location and ensuring a seamless biomass supply chain. A well-distributed road network with wide roads around the plant facilitates efficient and cost-effective biomass transportation. It enables accessibility to the biomass resource, optimal route planning and appropriate vehicle selection. Information about permits, regulations, scheduling and logistics also helps ensure uninterrupted and sustainable supply. Road and highway connectivity at the local, state or national level can be verified using Google or local maps.

Efficient BioCNG transportation – Driven by Ease of Handling and Minimum Storage Requirements

The enriched biogas (EBG) can be transported through technically compliant gas pipelines, in cascade compressed form and liquid form using tankers. The EBG's end-use application largely determines storage and transportation choices. The EBG, compressed at 6 to 15 bar pressure to make BioCNG, can be injected into the local or city gas distribution (CGD) networks for domestic cooking, CNG vehicles and industry. Synchronizing with the CGD is the most efficient mechanism for ensuring uninterrupted transportation of EBG from the plant site by significantly reducing transport and storage infrastructure needs. Potential BioCNG-CGD synchronization and integration points, such as pressure regulating stations (PRS)[20] and tap-off points,[21] need to be mapped for the pre-feasibility assessment framework. This requires engaging with CGD entities or gas marketing companies operating in the region.

Siting an EBG production plant in areas without a CGD network is possible. Provided the demand for natural gas exists through the presence of retail CNG gas stations or manufacturing and industrial estates requiring natural gas, EBG can be converted into BioCNG at a compression rate above 200 bar for storage and transportation using cascades for short distances in the range of 25 to 30 km. This is a preferred strategy for locations where gas marketing companies are providing services by transporting CNG in cascades for distances up to 75 km. The strategy requires mapping all operating CNG stations and natural gas-dependent manufacturing and industrial estates as a key input for the pre-feasibility analysis. Liquefying EBG is only suitable when it needs to travel distances greater than 100 km.

Demand for Fermented Organic Manure and Access to Market

Assessing the suitability of FOM (or enriched FOM[22]) for crops and its potential to replace inorganic fertilizer requires an understanding of the cropping patterns in the region and the predominant irrigation practice. Further, understanding the region's existing demand for inorganic and organic fertilizers will help in estimating future demand levels for FOM under various scenarios. A GIS heatmap should be prepared that details the total cultivable area in the region and highlights the levels of suitability of enriched FOM for different cropping patterns.

Engaging and partnering with fertilizer companies in the region provides an opportunity to access the conventional fertilizer market and leverage the existing network and infrastructure to introduce enriched FOM to consumers and create demand. Fertilizer companies in the region should be mapped during the pre-feasibility analysis.

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20 Pressure Regulating Station (PRS) – PRS are points for reducing the pressure of natural gas flowing through pipelines network from 50 bar to 6 bar approximately.

21 Tap off point (TOP) - TOP means a facility on the pipeline from where the petroleum products are diverted into a delivery terminal or into a spur line or another pipeline which may also be called the intermediate delivery station.

22 Enriched FOM – FOM produced from the BioCNG plant is enriched to produce value added organic fertilizer such as organic phosphate fertilizers, organic potash fertilizer, organic silica fertilizer, organic sulfur fertilizer, organic micronutrient fertilizer, and carbon rich organic manure, to replace FOM's chemical counterparts.

Biogenic CO2

Industry sectors, including fertilizer manufacturers, food and beverage producers, chemical water treatment and electronics manufacturing, use CO2 as a process input in addition to greenhouse agriculture. The demand for biogenic CO2 is likely to replace the demand for fossil-based CO2. To estimate the likely demand for biogenic CO2, it is advisable to identify potential users during the pre-feasibility analysis. Capturing CO2 has other co-benefits, such as potential carbon revenues (from carbon credits) and helps in securing environmental clearances.

Identifying the Hotzone and Optimal Plant Location

Developing a sustainable BioCNG project requires comprehensive resource, technical and market assessment to minimize risks and ensure the project's suitability and viability. The results of the pre-feasibility analysis determine the potential hotzone for the project. In regions with competitive biomass usage, the hotzone's demarcation can also be used to restrict the transportation of resources outside the boundary and/or usage for competitive applications within the boundary, improving project viability, sustainability and bankability. Mapping the hotzone involves setting the operational boundaries, engaging with key local stakeholders, assessing biomass resource availability, estimating BioCNG demand, evaluating the basic enabling infrastructure and appraising the local socio-economic-political situation, among other aspects.

The seamless connectivity of plant location with both the road network for transporting biomass and plant products and the nearest product receiving station (PRS) or transportation loading point (TOP), in case of integration with CGD, are key to determining the plant's optimal plant. Further, water-stressed regions in the hotzone should be avoided, considering the plant's significant water requirement.

Technology, Innovation, and Automation

A critical factor for sustainable BioCNG projects is the selection of flexible and suitable digestion technology, which should be based on its ability to process multiple feedstocks of varied quality and quantity and suitability for the climatic conditions in the region, including seasonal ambient temperature and humidity variation. Further, the soil load-bearing capacity and seismic zone category should be considered when designing the digester. Automation enabled data gathered from the plant operations not only helps to analyze and fine-tune processes and operations and improve performance but also helps establish the data-driven basis for securing insurance for performance and credit guarantees. A few innovative solutions with potential to achieve high efficiency for BioCNG projects, are highlighted in Box 3. An indicative Specification and Standards for a Green Field 10 TPD BioCNG Plant, is provided in Appendix III.

Achieving Financial Viability

A thorough financial analysis that considers the project's financial viability is imperative. The key aspects for analysis include the following:

Biomass procurement price: The fundamental principle for sustainable and affordable biomass procurement is securing a

Box 3 - Best practices to achieve high efficiency for BioCNG projects:

Best practices and innovative mechanisms for achieving high efficiency in the plant's operations are as follows:

Innovative feedstock storage to minimize loss and decomposition/degradation: For press mud storage, ensuring provisions for a leachate collection system at the bottom of the storage area minimizes loss by feeding the leachate into the reactor directly. Further, to mitigate the aerobic degradation of press mud, multiple protective layers of inert materials can be used between the press mud layers. This can potentially reduce the degradation of press mud by up to 70% for long-term storage requirements.

Circularity for enriched biogas and FOM: Biogas produced from press mud (as primary feedstock) generally has high sulfur content in the form of hydrogen sulfide (H2S). An efficient biogas purification and upgradation system can effectively extract the H2S and produce high methane biogas, potentially fetching a higher premium for higher calorific value biogas. In addition, the sulfur recovered from purifying biogas has the potential to produce enriched organic sulfur fertilizer (by mixing with FOM). A BioCNG project requires a large volume of water for the process. However, up to 70% of the water requirement can be met through recycling and reusing the water recovered from the digester slurry, and only 30% should come from fresh or mark-up water. These circularity options make BioCNG projects a self-sustaining and environmentally friendly energy transition intervention.

Maximizing product output: Operational efficiency is further strengthened with advanced instrumentation and system automation. These enable high levels of automatic system control and monitoring with minimal manual intervention, significantly reducing operational deviations and process faults. A Programable Logic Controller (PLC) based automated system manages the feed and other inputs material into the digestor based on the total solid content of each batch of feedstock, optimally controling the digestor's internal environment and maximizing biogas production.

biomass supply from reliable sources such as industries, farms, farmer producer organizations, municipal corporations, large HORECA (Hotels, Restaurants, and Cafes) entities, etc., at a mutually agreed price recorded in a long-term agreement. Further, the stability in the pricing of biomass such as paddy straw can be achieved through price benchmarking by the relevant public administration until the market has matured enough and is free from any contract defaults. Plantation of energy crops such as Napier grass can be adopted to mitigate any biomass supply shocks. An example of biomass price benchmarking driven by policy/ regulatory levers is given in Box 4.

Box 4 - Benchmarking biomass price:

Despite the evolving market conditions for biomass in India and a mandate for co-firing biomass pellets up to 10% with coal, neither supplier nor offtaker could close the transaction for a large quantity of biomass. Price benchmarking was the key barrier impeding market maturity. India's Ministry of Power (MoP) has approved benchmarking the prices for biomass pellets acquired from surplus agriculture residues and used for co-firing in thermal power plants. Co-firing of biomass in coal-based power plants is a key government policy that impacts energy security, fossil fuel reduction and increased farmer income. The benchmarking decision is intended to encourage farmers, entrepreneurs and end-users to establish a sustainable biomass ecosystem, reduce stubble burning and help ensure a cleaner and greener future. Price benchmarking of suitable feedstock for BioCNG projects would also help accelerate the uptake of sustainable and financially viable BioCNG projects.

Upfront investment: A well-designed or structured BioCNG project offers the potential to reduce the upfront investment. Significant reduction can be achieved for the projects where BioCNG is evacuated through pipelines instead of cascades. Cost reductions of up to 10% of the total project cost can be expected from replacing cascade capacity (with additional buffer capacity) and having a low pressure compressor requiring only six bar in pipelines against 200 bar in cascades.

Operational costs: Advanced instrumentation and automation minimize failures and enhance long-term continuous plant operation. Continuous operation significantly reduces the expenses for the plant's start-up and downtime periods and improves the reliability of plant performance.

Assured market-based offtake price for products (BioCNG, FOM, and Biogenic CO2): A long-term contract at a mutually agreed offtake price for products enables continuous cashflow. In the case of an underdeveloped or developing market for BioCNG/ FOM/Biogenic CO2, specific policy instruments, such as pricing signals, mandatory purchase obligation and market development assistance, shall be provisioned to bridge the short-term viability gap and achieve long-term market transformation.

Revenue streams and financial projections (including risk factors): Offtake of the products (BioCNG, FOM, and Biogenic CO2) creates a stable revenue stream for the projects. However, the carbon credits (or Internationally Transferred Mitigation Outcomes – ITMOs) generated from the BioCNG project can potentially improve financial viability as an additional revenue stream, achieving early payback and reasonable rate of returns through mobilizing carbon financing and mitigating the financial risks to some extent.

Ensuring Socio-Economic Benefits

A typical large-scale BioCNG project generates up to 50 direct and 500-plus indirect green jobs across the value chain, drives the economy and brings prosperity. Considering the complexity of BioCNG projects at the operational level, a large number of skilled and semi-skilled workforce are required for sustainable and efficient plant operation. Strengthening institutional and resource capacities emphasizes the need for training and capacity building at a large-scale.

c. Business Models and Investment Mobilization

Considering the prevailing market practices and challenges associated with a region's BioCNG sector requires implementing a suitable business model that attracts key stakeholders, enables partnerships, shares risk appropriately and creates a win-win for all. Shared risk-return (SRR) based business models led by different entities are discussed in Section 6. The business models are structured to accelerate the deployment of BioCNG projects through guarantees for financial risks and public investment by creating replicable templates and attracting private sector investment.

5.5 BioCNG – Scale-up Phase

The scale-up phase is the last and most critical phase for achieving a broader impact on the environment, reducing GHG emissions, and enhancing energy security. The scale-up phase can be achieved once certain business models are developed and tested through a handful of projects (see sections 6 and 7). Scale-up requires collaboration between policymakers, industry stakeholders, financial institutions and the public to create an enabling environment for the widespread adoption of BioCNG as a viable and low-carbon energy solution. Adopting robust project assessment frameworks to identify viable projects, increasing access to finance through investments from the private sector and financial institutions and building strategic partnerships for suitable business models can help replicate the success achieved in the implementation phase.

6. Business Models

Considering the complex nature of BioCNG projects and the crucial role of technical know-how for sustainable and optimal plant operation, creating a robust and suitable business model is vital for the successful implementation of a large -scale (commercial) biogas project. A well-designed business model facilitates complementary partnerships, maximizes revenue, manages costs and addresses potential risks – including investment, socio-political, operational and market challenges – helping to ensure long-term project viability and creating a win-win for all partners. Based on the market engagement and sector requirements for different scenarios in developing economies, three business models have been developed: (i) investor-led shared risk-return model, (ii) integrated solution provider-led model, and (iii) public-private partnership model. The selection of a suitable business model should be based on the type of project, stakeholder and local policy and market ecosystem, and business models should be tailored to create a win-win among key stakeholders.

6.1 Investor-Led Shared Risk-Return

The investor-led shared risk-return (ISRR) model is suitable for countries and regions with partially evolved BioCNG markets, as evidenced by the presence of an enabling policy and regulatory ecosystem. However, investing in BioCNG projects is often considered risky due to an underdeveloped ecosystem for service and solution providers. Creating a template for replication that includes a pool of credible and serious service and solution providers and demonstrates technology performance at scale is a key objective in the ISRR business model.

An investor or group of investors is setting-up a Special Purpose Vehicle (SPV) to make a 100% investment into the project. The project's return on investment is likely to be lower than regular market-based investment returns – considering BioCNG is yet to achieve parity with fossil fuels available in the market. Therefore,

public sector participation is crucial for the initial few projects. Public sector entities in the oil, gas and fertilizer sectors represent the type of investors that can feasibly support BioCNG's growth.

When an SPV selects an Integrated Solution Provider (ISP), a company or a consortium of technology and local engineering, procurement, and construction (EPC) partners undertake the project design, development, operation and maintenance as their key responsibilities. They are also responsible for ensuring sustainable biomass supply, achieving optimal plant performance, and maximizing revenue realization. Figure 15 schematizes the ISRR's operational and financial flows.

Investment risks in the ISRR are partially mitigated or shared through guarantee-based participation of the ISP, such as a financial bank guarantee of up to 20-30% of the project investment until 100% of the principal investment is paid back before the closure of the principal payback period. The net profit from the project is used to pay back the principal investment amount.

After the principal payback period, the ISP becomes part of SPV. Further, the net profit from the project is shared among the investor(s) and ISP in proportion to the expected return or opportunity cost associated with the investment or bank guarantee. The net profit sharing can be based on a pre-agreed formula and may include factors such as the extent of investment risk covered through the bank guarantee. Figure 16 presents an illustrative profit sharing mechanism.

Demonstrating a few projects based on ISRR, will create an ecosystem of services by mitigating perceptions of risk perception, establishing models for sustainable biomass supply, developing technology knowhow, among others. Once the ecosystem is established and sufficient understanding is developed regarding the BioCNG projects, provisions like bank guarantee commitment against the investor's equity may be waived. Further, it will move the market from balance sheet based financing to project based financing, attracting funding and investment from commercial banks and the private sector. A techno-economic analysis based on ISRR for a Green Field 10 TPD BioCNG plant, is presented in Appendix IV.

6.2 Integrated Solution Provider-Led

The integrated solution provider-led (ISPL) model is suitable for countries and regions where the policy and regulatory ecosystem is in the initial phases of evolution but where BioCNG projects are nevertheless viable at an industrial scale. The scenario is ideal for an Integrated Solution Provider seeking to enter the market early and become the market leader by successfully demonstrating the application of technology and making the case for accelerated scale-up in the region or country. With focused target sectors and industries, such as food processing, sugar mills, and palm oil mills, among others, the ISP has a reliable feedstock supply, thereby reducing the project and investment risk substantially.

Figure 15. Operational and financial flow for an investor-led shared risk (ISRR) return model

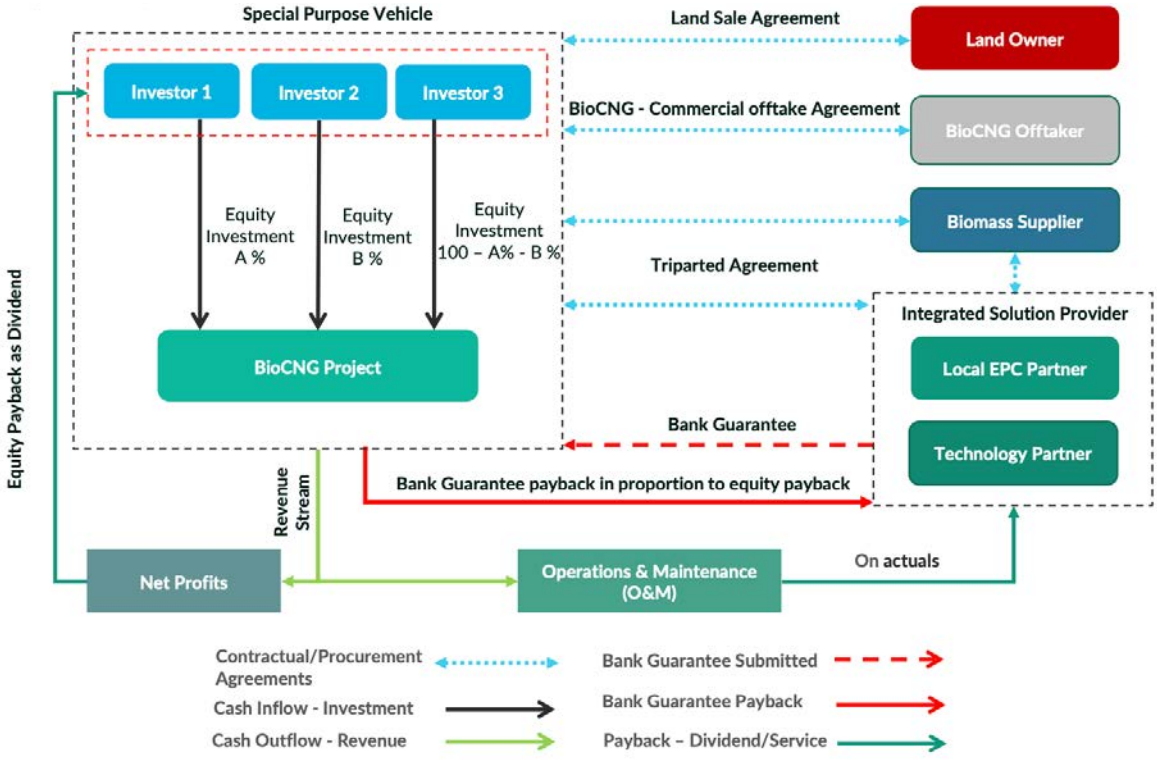
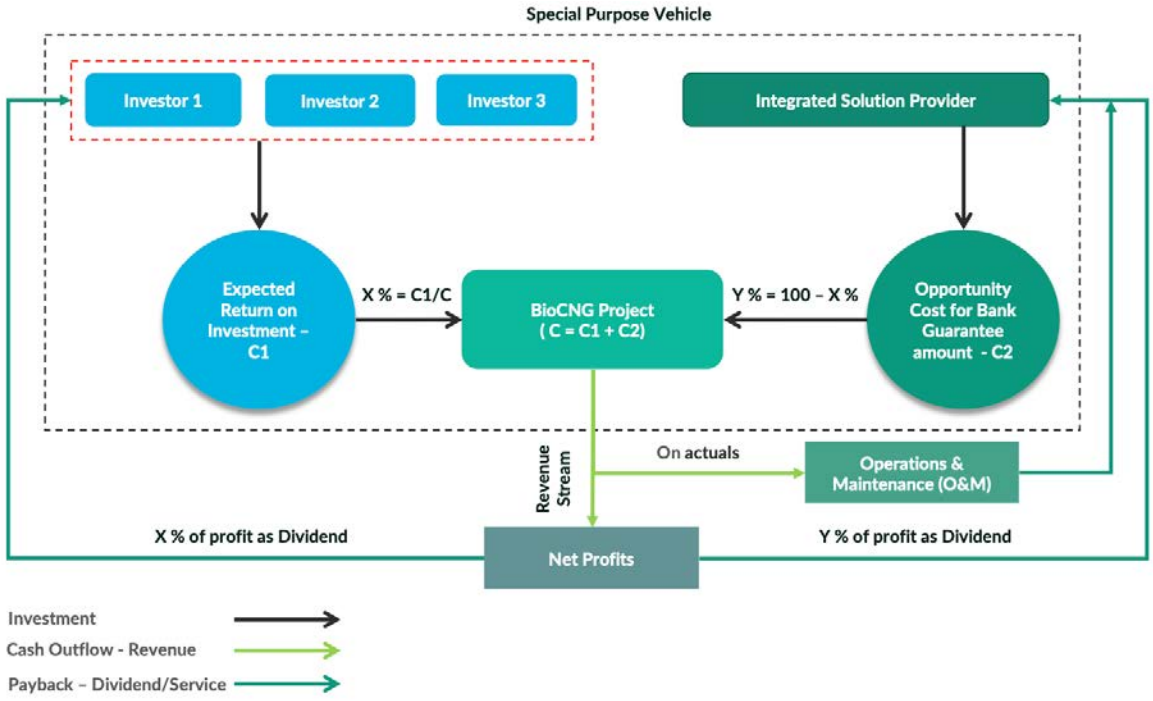


Figure 16. Project financial flow – post-principal payback period



An SPV should be formulated in partnership with the ISP and the biomass supplier (mainly industry), with equity-based participation. The high bankability of the project resulting from its reduced feedstock supply risk can be leveraged to raise equity. Further, the higher bankability and the industry's balance sheet can help catalyze debt for the project. Industry can also offer land for the project's development to enhance the project's profile.

The ISP undertakes responsibility for project design, development, operation and maintenance, including achieving optimal plant performance and maximizing revenue realization. However, the biomass supplier will ensure sustainable supply, including the desired quality and quantity. The biomass supplier, such as the local sugar industry, can potentially also be the BioCNG offtaker. The operational and financial flow for the ISPL is presented in Figure 17. The replicability of the ISPL approach and scale-up of the resulting BioCNG project would be high due to the inherent risk mitigation feature of the business model. These projects would also be a source of best practice and technology benchmarking for BioCNG based on other feedstocks and create an ecosystem that accelerates the growth of the BioCNG sector in the region or country.

6.3 Public-Private Partnership

The public-private partnership (PPP) model is the most suitable business model for effectively and sustainably managing municipal solid waste, primarily the organic fraction of MSW. The PPP approach is best suited for scenarios where the BioCNG technology is proven and performing well and the policy and regulatory ecosystem is in the initial phases of evolution.

An SPV would be formulated in partnership with the investor (presumably from the private sector) and a government agency or municipal entity, with equity-based participation. Such projects have a high bankability due to (i) reduced feedstock supply risks, (ii) round-the-year availability, and (iii) minimum or zero biomass price, which can be leveraged to catalyze debt. Requirements for supplemental biomass can be secured through additional biomass supplier agreements. The municipal entity or relevant land-owning agency confirms the land required to develop the project, which helps reduce the project's gestation period. Considering the high demand for fuel in cities, the assessment of potential revenue can forecast a premium price for BioCNG. The ISP is selected through a competitive bidding process, with the key criteria possibly including minimum project cost, assured plant performance), minimum operation and management costs and longer plant life, among others. Figure 18 outlines the PPP model's operational and financial flow.

The PPP models' replicability across multiple cities in target countries is high due to their inherent risk mitigation feature and strong financial viability and sustainability. Also, PPP projects require minimal supervision, which makes them suitable for scale-up and replication.

Figure 17. Operational and financial flow for Integrated Solution Provider led business model

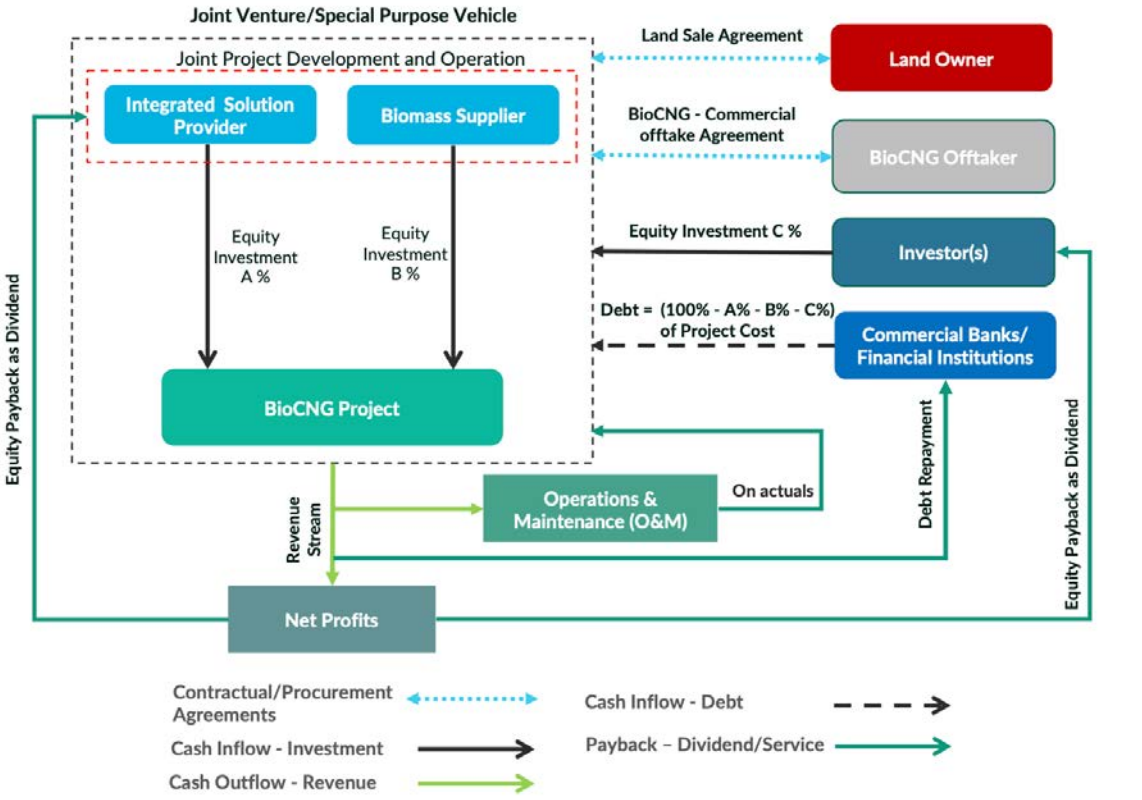
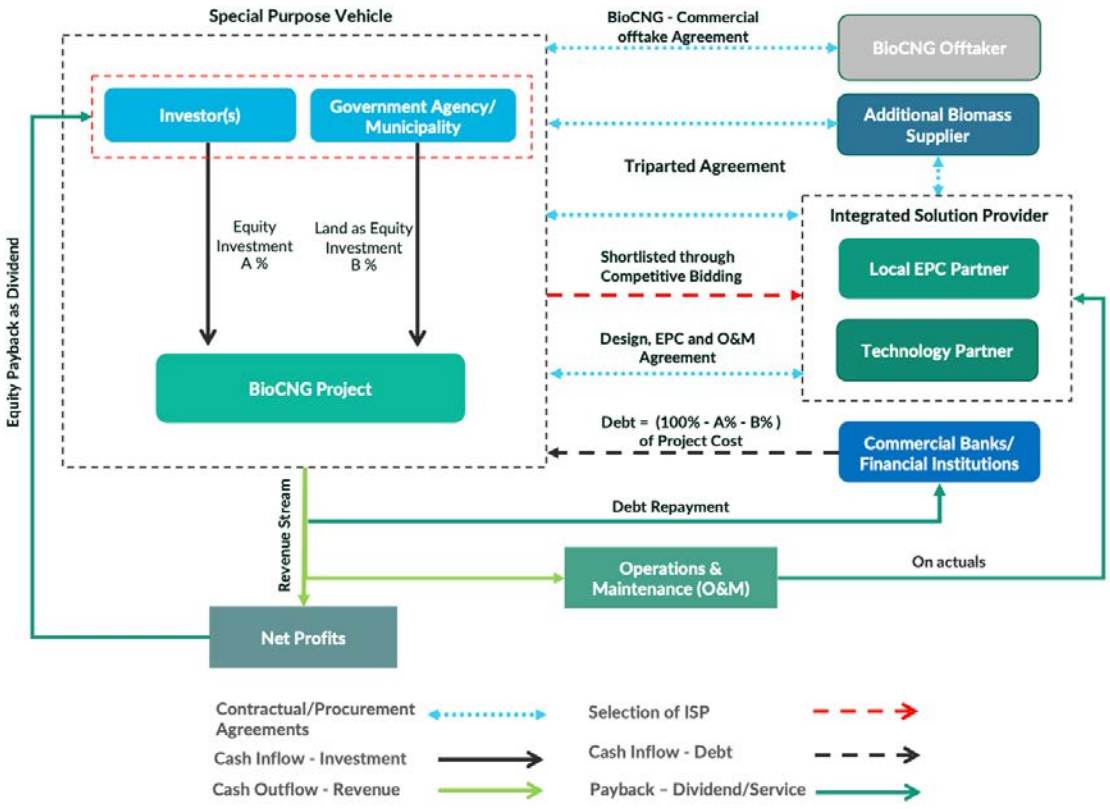


Figure 18. Operational and financial flow for Public-Private Partnership business model



7. BioCNG Project Development Workflow

A BioCNG project typically involves several stages of development, which can vary depending on the specific methodology or framework being used. For a BioCNG project, the initial stages are its preliminary and detailed assessments. Based on its evaluation criteria, the project may be moved to the later stages of project design, structuring, financing and implementation. Figure 19 outlines the stages and steps in developing a BioCNG project and its tentative outputs.

7.1 Preliminary Assessment

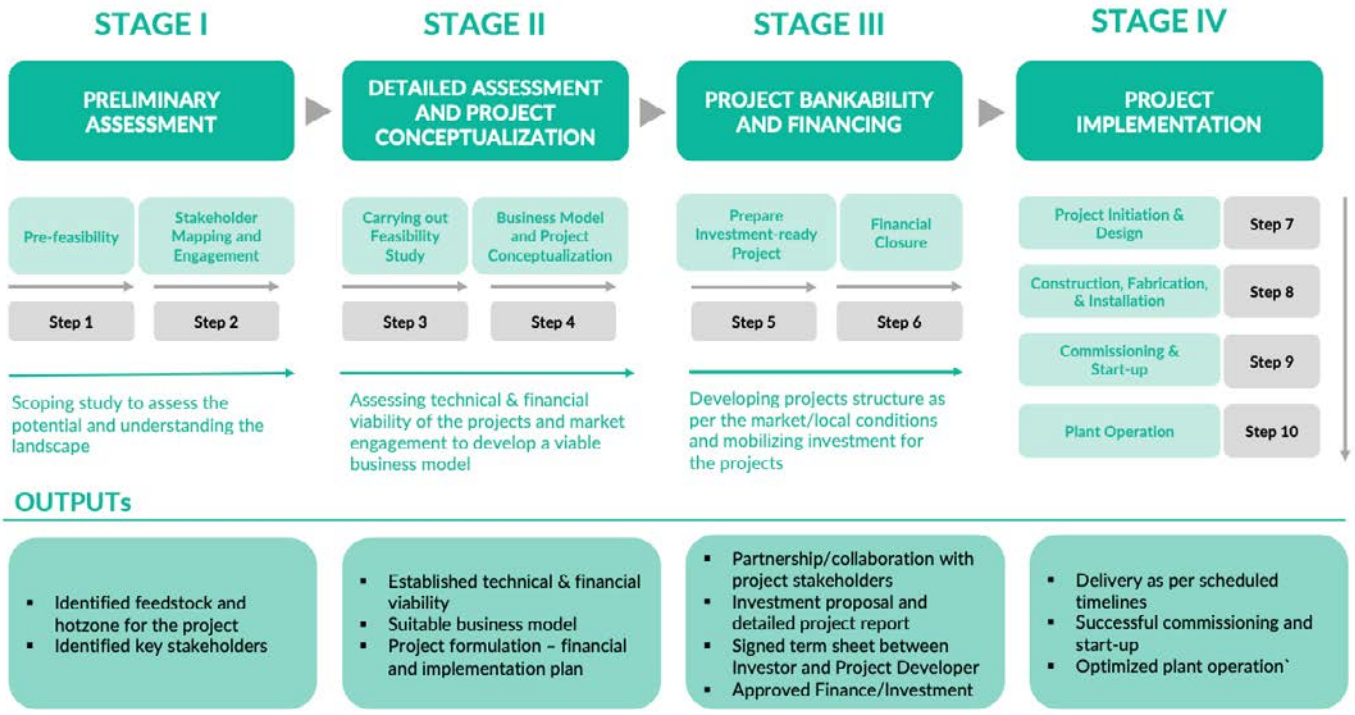
Step 1: Pre-feasibility studies

A pre-feasibility study, based on secondary sources and data, will help determine the merit of proposed investment options and assess whether to move to the next stages of development. These include a full feasibility study and, if the decision is made to proceed, project design and securing access to finance. The hotzone in the target region will be identified based on various technical, financial, social and environmental parameters. Resource potential, biomass type and optimal plant location, among others, are the key findings of the pre-feasibility analysis. Section 5.4.b describes the methodology for undertaking pre-feasibility studies of BioCNG projects.

Step 2: Stakeholder Mapping and Engagement

Stakeholders such as biomass suppliers, project developers, technology and EPC companies, BioCNG offtakers, FOM offtakers and distributors, and relevant government agencies are mapped and consulted to understand the market and the policy and regulatory landscape.

Figure 19. Stages and steps in developing a BioCNG project and tentative outputs



7.2 Detailed Assessment and Project Conceptualization

Step 3: Carrying Out the Feasibility Study

The feasibility study validates the pre-feasibility analysis and checks the proposed project's technical suitability based on technical field investigations and primary data. A field survey by the CGD entity to identify the tap-off point near the plant location is one of the key parameters. The project's operational viability and bankability are assessed with an overview of the investment's context, including the estimated project cost, the project's social and environmental impact, the net present value, the payback period and the financial returns. Further, a sensitivity analysis is conducted to assess the impact of key financial ratios. Finally, the feasibility analysis assesses the project's risk and mitigation measures.

Step 4: Business Model and Project Conceptualization

Building on the insights from the feasibility analysis and incorporating de-risking measures, a suitable business model is developed that ensures project suitability, formulates complementary partnerships and develops a win-win scenario. Decisions regarding technology based on feedstock choice are central to the technical and financial aspects of project designing (Table 1 describes the suitability of different types of anaerobic digesters). A project is conceptualized and structured before a budget is prepared that allocates resources and financial planning in line with the project's delivery schedules.

7.3 Project Bankability and Financing

Step 5: Prepare Investment-Ready Project

Based on the business model and project structure, a request for proposal/quotation (RFP/RFQ) is prepared, inviting competitive submissions from technology providers, EPC companies, biomass suppliers, product offtakers, partners and stakeholders, among others. Some or all the stakeholders/partners can also be selected through bilateral contracts and agreements. An investment proposal is then prepared to mobilize the project's required finance.

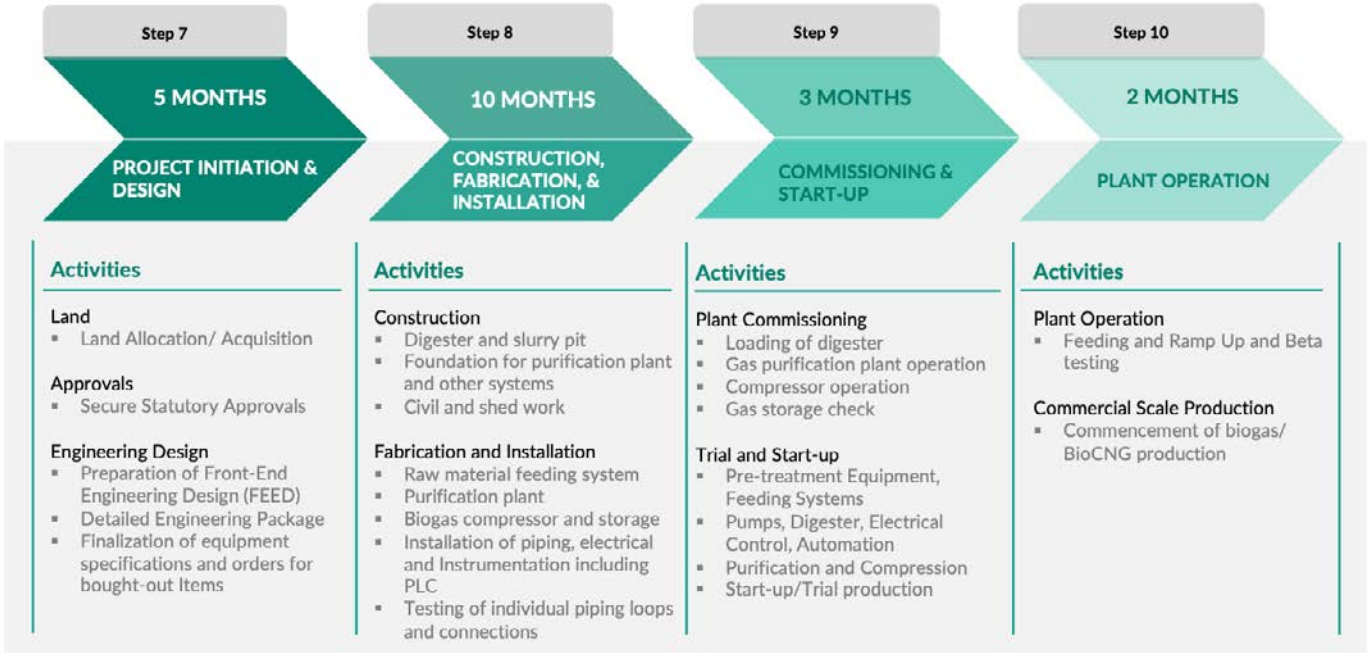
Step 6: Financial Closure

Following the preparation of the investment proposal, the next step is engaging with investors and/or financial institutions, including commercial banks, to mobilize project funding. This includes discussion to reach a mutual agreement on the terms regarding the financial arrangement.

7.4 Project Implementation

There are multiple steps in implementing a BioCNG project. These include land acquisition, statutory approvals, engineering design of the plant, construction, fabrication and installation, commissioning, trial runs, and commercial operation. Figure 20 provides an overview of the key activities and timelines for each step in the project implementation phase.

Figure 20. Key activities and timelines for each step in the project implementation phase



Source: GGGI

8. Summary of Recommendations and Conclusion

The use of biogas as a renewable energy source has gained increasing attention in recent years due to its potential to reduce greenhouse gas emissions and promote sustainable development. This report offers an overview of best practices and case studies related to compressed BioCNG production and utilization across various industries, as well as policy recommendations for promoting the development of the BioCNG sector.

The report has highlighted the economic, environmental, and social benefits of BioCNG, including its potential to reduce greenhouse gas emissions, create jobs, and promote rural development. The best practices and case studies presented in the report showcase the potential of BioCNG production and utilization in various industries, including transportation, power generation, and cooking. The case studies have also highlighted the different business models and financing mechanisms used for BioCNG projects, as well as the regulatory frameworks and policy incentives that have supported their development.

The report clearly acknowledges the issues the emerging sector needs to resolve, including the lack of awareness and understanding of BioCNG, the high capital costs of BioCNG projects, and the lack of supportive policies and regulations. However, it provides a suite of recommendations for addressing these and other challenges.

The consolidate country-specific lessons learned are outlined as a set of general recommendations, in this section. These recommendations are intended to serve as strategic guidelines applicable to diverse countries aspiring to foster a sustainable BioCNG sector. By amalgamating insights from specific contexts, we aim to provide a cohesive set of principles for effective and inclusive development. The following recommendations emerge as key focal points for stakeholders and policymakers.

- **Strategic Biomass Mapping:** To establish a long-term, sustainable biomass supply, it is recommended to develop a mapping methodology for identifying viable projects.
- **Innovative Business Models:** To ensure sustained project performance and output, explore and develop innovative business models to effectively de-risk BioCNG projects.
- **Investment Mobilization Mechanism:** To facilitate investment in BioCNG projects, consider implementing interest rate subventions, loss/risk guarantees, and other financialinstruments as part of an effective mobilization mechanism.
- **National Strategy Integration:** To integrate BioCNG into the national strategy for Liquefied Petroleum Gas (LPG) and

Compressed Natural Gas (CNG)substitution, establish specific targets and policies that promote the production, distribution, and consumption ofBioCNG as a viable and environmentally friendly fuel option.

- **Legal and Technical Clarity:** To encourage BioCNG investment, consider implementing standardized legal and technical business classifications defining the primary activities, products and services BioCNG businesses deliver.

- **Quality Benchmark Development:** To ensure the quality of BioCNG, countries should consider developing their own national standards, incorporating best practices from other countries and seeking input from local producers and associations.

- **Integration into the Gas Grid:** To create an enabling environment for BioCNG development, explore the benefits of injecting BioCNG into the existing gas grid. Commit to regulatory adjustments, address infrastructure needs, and engage stakeholders to facilitate integration.

- **Regulatory Framework for Digestate Use:** To enhance the financial viability of bioenergy projects, develop a regulatory framework for the responsible and safe use of digestate on land. This will help avoid unnecessary investments in separate waste treatment plants.

- **Transparent Policy for Fossil Fuel Replacement:** To encourage the transition from fossil fuels like LPG to BioCNG, consider announcing an open and transparent policy to provide clarity and support for the shift to cleaner energy alternatives.

The policy recommendations presented in the report provide a roadmap for promoting the development of the BioCNG sector based on the experiences of BioCNG projects in developed and developing countries, with a particular focus on India, Indonesia and Thailand. The recommendations cover a range of policy areas, including feed-in tariffs, tax incentives, regulatory frameworks, and capacity building. The recommendations also stress the significance of public-private partnerships and international cooperation in promoting the development of the BioCNG sector.

In summary, this report underscores the potential of BioCNG as a sustainable energy source and its role in the circular economy. The best practices and case studies presented in the report provide valuable insights for promoting the development of the BioCNG sector. At the same time, the policy recommendations offer a roadmap for policymakers and investors. The report demonstrates that the development of the BioCNG sector can contribute to the achievement of the Sustainable Development Goals and the transition to a low-carbon economy.

In conclusion, GGGI trusts this report will encourage and help policymakers, investors and stakeholders accelerate the growth of the BioCNG sector. Embracing the report's recommended best practices and policies can enable nations to unlock the full potential of BioCNG, driving sustainable and inclusive growth. Creating an enabling environment for the BioCNG industry will help create a sustainable future for all.

9. Detailed Case Studies from GGGI's BioCNG Interventions

9.1 Case Study – Promoting BioCNG in India

a. Design Phase

Strategic Partnership and Stakeholder Engagement

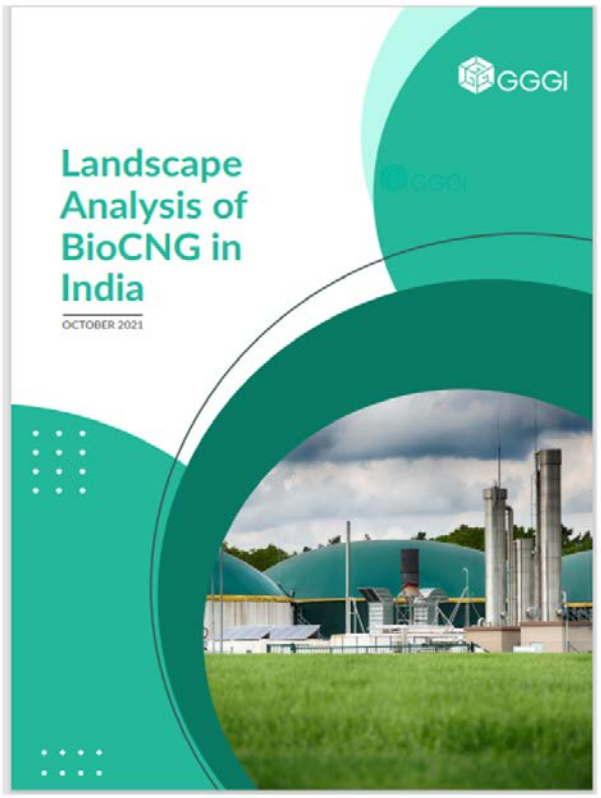
GGGI, under the BioCNG Program, has a Memorandum of Understanding (MoU) with India's Ministry of Petroleum and Natural Gas (MoPNG). The Ministry fosters an enabling environment for BioCNG projects by addressing technical and regulatory challenges, developing viable business models, providing appropriate policy incentives, catalyzing multi- and bilateral funding and building institutional capacity. The project's objective is to create a template for replication and help the MoPNG achieve a target of deploying 5,000 BioCNG projects by 2024. GGGI partnered with sub-national government agencies in the states of Haryana and Punjab, including an MoU with the Haryana Government's Renewable Energy Development Agency (HAREDA). Copies of the MoUs signed with MoPNG and HAREDA are available in Appendix V. GGGI has also engaged with leading engineering and technology companies such as Technip Energies, Texol and others to create an ecosystem of service providers for large-scale BioCNG projects.

Landscape Analysis – Gap and Barrier Analysis and Opportunities

A comprehensive landscape analysis was undertaken outlining key aspects, including India's energy context and its BioCNG and bioenergy ecosystem. The analysis looked at the technology landscape, bioenergy growth, feedstock and resource availability and biomass potential. It also examined supply chain logistics for biomass and BioCNG, enablers and opportunities, and barriers and challenges. See the GGGI report, "Landscape Analysis of BioCNG in India", for further details.

The report addresses a range of issues and questions a successful BioCNG sector will need to address. These include feedstock availability, feedstock quality, multiple feedstocks, technology, BioCNG by-product marketing, financing and implementation, among others.

The key enablers for the growth of the BioCNG sector in India include assured offtake of BioCNG, oil and gas marketing companies facilitating the marketing of FOM produced from the BioCNG plants, large gas distribution networks across India's cities, and fiscal incentives such as the Foreign Direct Investment (FDI) initiative, concessional customs duty, accelerated depreciation, and a concessional goods and service tax of 5%, among others. Furthermore, the target production of 15 million tonnes per annum of BioCNG from 5,000 plants by 2024 under the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative presents a huge opportunity. As per the SATAT targets, the industry players are expected to invest USD 24 billion (INR 175,000 crore) in infrastructure development for BioCNG distribution. It is anticipated that this initiative will generate jobs for 75,000 people and produce 50 million tonnes of FOM as an alternative to inorganic fertilizer.



b. Implementation Phase

Policy Advocacy to the policymakers

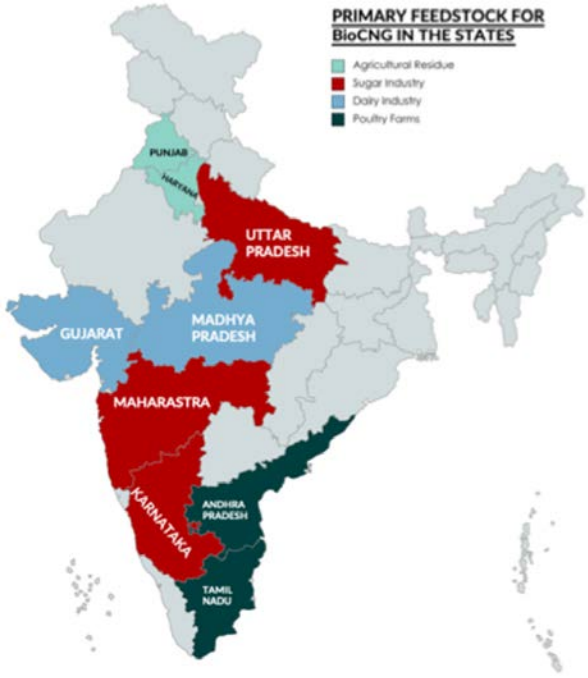
GGGI has prepared a report entitled "Policy Recommendations to Accelerate Implementation of BioCNG Projects under SATAT Initiative", advocating various recommendations to promote the uptake of BioCNG. These include revising the BioCNG offtake price and creating demand for FOM offtake, among others. After submitting the report to the MoPNG, oil and gas marketing companies (OMCs) in India revised the guaranteed offtake price for BioCNG, increasing it by 20% from the base price, and indexed the BioCNG price with the natural gas market price. This has created a financial incentive for private sector participation in the sector. For further information about the GGGI's BioCNG recommendations for India, see its "BioCNG Policy Recommendation Report".

The Government of India has revised the BioCNG offtake price and indexed it with the CNG market price, as highlighted in the GGGI's policy recommendations report. This one policy change has created a positive enabling environment for private sector participation. The notification issued regarding the "BioCNG Procurement Price Index in India" can be accessed using the Link (https://satat.co.in/satat/assets/download/CBG%20Pricing%20Circular%20-%20Stakeholders.pdf).

Pre-feasibility, Feasibility Analysis, and Project Identification

The pre-feasibility report (PFR) assesses the techno-commercial viability of setting up BioCNG projects in the region. Identifying sustainable and affordable biomass supply sources in a defined catchment area has been the starting point in determining project location and capacity. It would be prudent to undertake a broad-level pre-feasibility study, at least at the district level, to identify hotzones based on sources of biomass available in a region, including industrial waste, municipal organic waste, agricultural waste, etc. Selecting a site for setting up BioCNG projects depends on various technical and non-technical parameters. Based on consultations with various stakeholders, GGGI has devised a pre-feasibility criterion to assist OMCs and developers in identifying possible hotzones in a district using GIS mapping. Figure 21 highlights the target regions for resource mapping and project identification in India.

Figure 21. Target regions in India for resource mapping and project identification



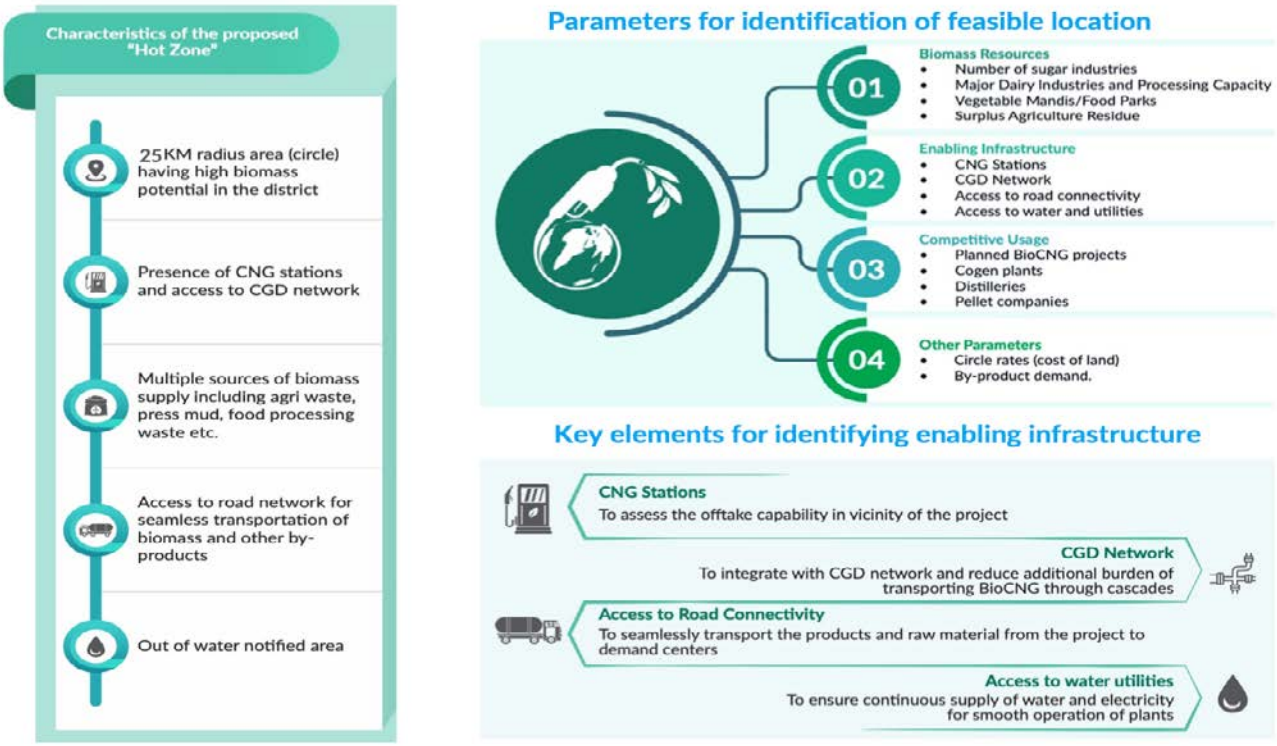
A detailed assessment to identify and map the potential hotzones has been undertaken in target regions. A suitable hotzone for a BioCNG plant was defined based on the availability and amount of biomass resources, BioCNG demand, notified areas for control and regulation of ground water, and ease of operation, including CGD networks, the availability of CNG stations and connectivity to roads and highways. Figure 22 provides the key parameters for assessing enabling infrastructure, mapping resource sufficiency and sources, and identifying feasible locations.

The first step is to identify the key parameters that directly influence the project's operations and viability. To filter out and identify the hotzone in the respective regions, a four-layered approach that includes key supply-side and demand side factors has been applied in mapping and assessing the regions across various data parameters. To identify hotzones and map layers pertaining to various data points, the framework leveraged open-source Quantum Geographic Information System software to develop various layers on biomass resources, enabling infrastructure, competitive usage and other critical parameters. Figure 23 illustrates the use of supply and demand side assessments for identifying potential hotzones.

The supply-side assessment in Figure 23 estimates the biomass potential of large centralized sources such as sugar mills, fruit and vegetable markets, cattle farms, dairy and food processing factories, and distributed resources such as agriculture residues.

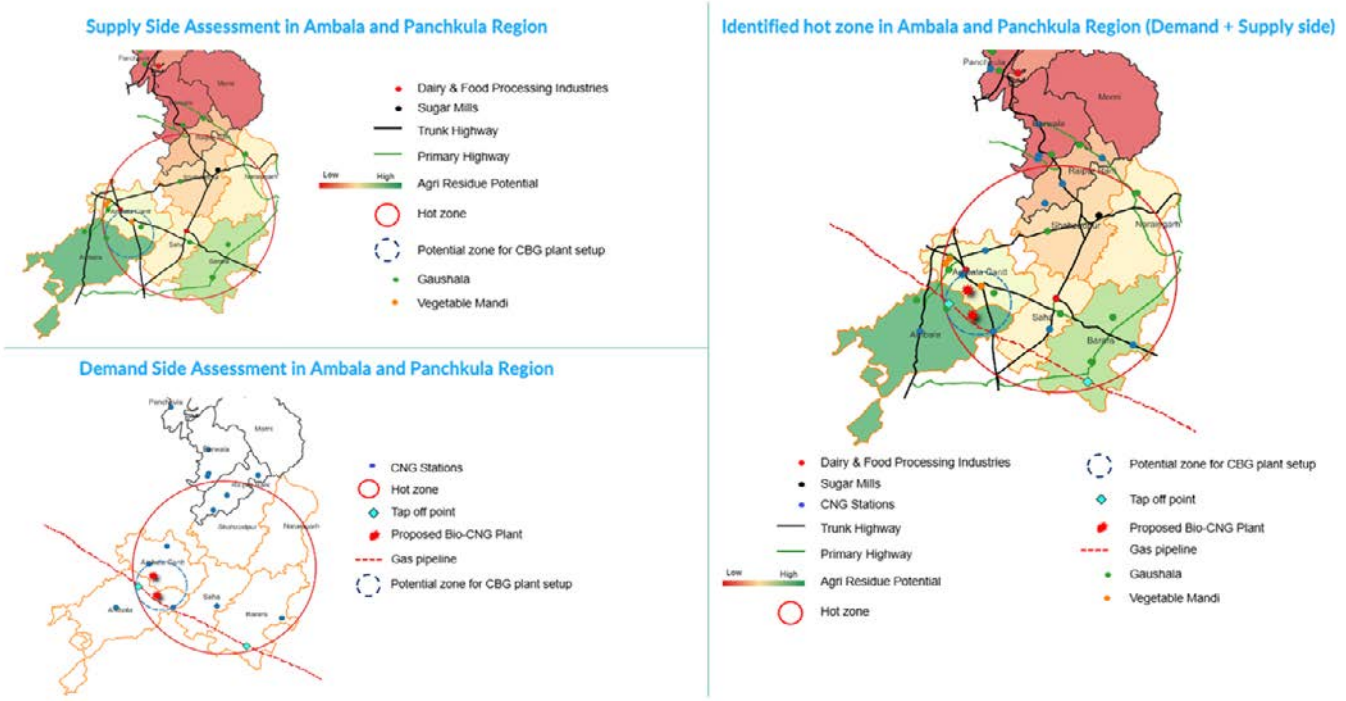
Further, the existing competitive uses of biomass, such as using agricultural residues in cogeneration plants and pellet companies,

Figure 22. Assessing enabling infrastructure, resource sufficiency and potential locations



Source: GGGI

Figure 23. Supply and demand-side assessment to identify potential hotzones



Source: GGGI

have been assessed. Existing or upcoming BioCNG plants in the region also increase the supply-side risk to securing biomass sustainably and are a key factor in identifying the hotzone. Logistics are crucial factors in determining efficient and effective project operations and have a direct impact on a project's expected returns. Therefore, major roads and national highways have been mapped in the supply-side assessment to estimate road connectivity for ease of transportation.

The demand side assessment mapped the potential BioCNG offtake points, such as existing CNG stations and tap-off points, to understand the enabling infrastructure's availability for sustainable and continuous evacuation and offtake of BioCNG.

The supply and demand side assessments have been overlayed to demarcate and identify potential hotzones with a 25 KM radius. Further, strategic project location identification has been based on several parameters, such as the proximity of potential demand, grid injection points for BioCNG, road networks and access to electricity and water.

The BioCNG projects identified can process 225 to 300 tonnes per day of mixed organic waste, such as press mud, cattle dung, vegetable market waste, paddy straw, poultry litter, and organic waste from factories and markets. Each project will generate an estimated 10 tonnes per day of BioCNG and 60 to 70 tonnes of solid FOM. Indicative specifications and standards for a 10 tonnes per day (TPD) BioCNG plant are available in Appendix III.

Business Models and Investment Mobilization

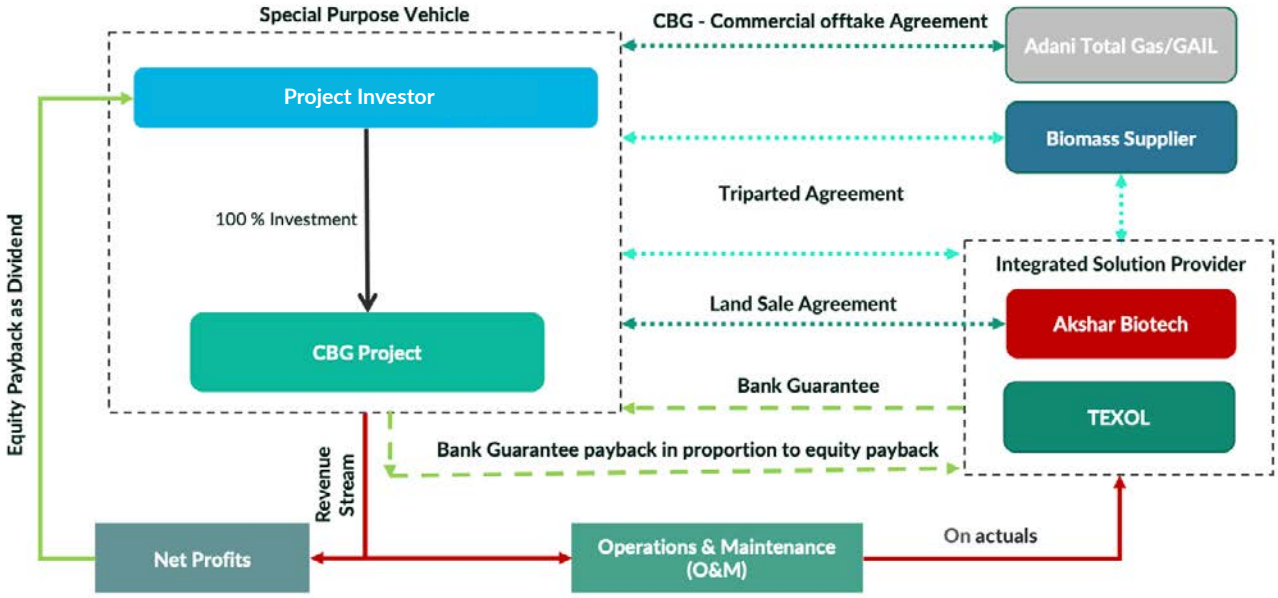
Based on the prevailing market practices and challenges associated with the BioCNG sector, GGGI has developed a Shared Risk-Return Business Model. The model guides the project in bringing together various stakeholders, such as investors, ISPs, biomass suppliers and offtakers, and apportioning a risk-return profile that creates a win-win scenario for all participants. Figure 24 illustrates the business model developed for the project in Navsari, Gujarat.

Based on this model, GGGI received a positive response from the investors, leading to a partnership with Indian Potash Limited (IPL), an organization of strategic importance to the Government of India. Under the partnership, the IPL has committed to invest USD 30 million in the BioCNG projects. ReNew Power, one of India's leading renewable energy companies has also committed to investing USD 30 million. GGGI has engaged with other potential investors to mobilize financing for India's BioCNG.

c. Scale-up Phase

GGGI has undertaken detailed feasibility studies for eight large-scale BioCNG project sites. The ISP – a partnership between a renewed EPC company and a local project developer – has prepared a detailed techno-commercial report and made an offer to the investor for the projects. At the time of writing, negotiations on the term sheet between the investor and the ISP remain ongoing.

Figure 24. Business model developed for a BioCNG project in Navsari, Gujarat



Source: GGGI

Under the GGGI BioCNG Program, systematic engagement has been conducted with all stakeholders, including policy makers, investors, technology providers, EPC companies, biomass suppliers, CGD entities, and FOM offtakers. The program's interventions have played a key role in the overall development of a BioCNG ecosystem in India. The program's key interventions that will further accelerate the deployment and scale-up of BioCNG projects in India are as follows:

- **Enabling policy environment:** created an enabling policy environment for developing BioCNG projects through stakeholder engagement and providing a recommendations report.
- **Project assessment framework:** developed a robust project assessment framework to identify high-quality potential project sites through a scientific assessment and design sustainable and viable projects.
- **Suitable business model:** prepared a viable business model based on shared risk and return to bring-in stakeholders in a manner that de-risks projects and offers incentives, ensuring its long-term engagement and benefiting all stakeholders.
- **Catalyze green investment:** secured financial commitments from public and private sector investors through the use of suitable business models.
- **Ecosystem for services:** supported the creation of an ISP that can cater to investor demand.
- **Model agreement document and facilitating discussions:** initiated commercial negotiations between investors and ISPs based on a draft term sheet. A copy of the draft term sheet can be found in Appendix VI.
- **Replication and Scale-up:** created a template for replication and scale-up through the deployment of model projects that will further mobilize private and financial sector investment, as most of the risks have been addressed in the project's design. Box 5 presents an example of using risk-sharing financing instrument to mobilize investment for BioCNG projects.

d. Lessons Learned

- **Strategic Partnership:** Formulating strategic partnerships with the national government is critical for an emerging sector such as BioCNG, where national level policies and regulatory interventions are critical for creating a level playing field. In contrast, regarding project-specific barriers, it is important to liaise with the relevant sub-national government agencies where the projects are located.
- **Institutional Capacity Building:** Government policy formulation should be based on evidence. In India, for example, a letter of intent (LOI) was issued to interested project

Box 5 - Risk Sharing Facility (RSF) – to mobilize commercial finance and accelerate BioCNG project deployment:

Interventions made in the initial and implementation phases created an ecosystem with an enabling policy, verified suitable business models, provided a robust project evaluation framework and demonstrated model projects for determining benchmarks and replicable templates. Building on these interventions, financing instruments such as the Risk Sharing Facility can help accelerate and achieve scale-up of BioCNG projects in India through private sector participation.

The World Bank has proposed a risk guarantee mechanism of USD 150 million for BioCNG, while the Global Environment Facility (GEF) has committed USD 13.75 million. The guarantee fund is intended to develop a risk-sharing mechanism that will enhance credit and mitigate risk in the value chain to mobilize financial resources to support the development of 100 large-scale BioCNG plants through an additional USD 550 million in the form of commercial equity and loans.

The RSF facility intends to support 20 organic municipal solid waste-based and 20 paddy straw-based BioCNG projects. The Small Industries Development Bank of India (SIDBI) has been identified to establish and operationalize the RSF. SIDBI will design and offer partial credit guarantees (sub-guarantees) to commercial banks and Non-Banking Financial Companies (NBFCs) to provide commercial loans to BioCNG developers.

developers without any specific resource mapping or strategy to create an enabling ecosystem. The limited institutional capacity and the ineffective LOI allocation resulted in a very small project realization ratio. Building institutional capacity to identify and tag projects with an LOI allocation and improving the allocation mechanism can potentially result in a higher project realization ratio.

- **Risk Management Approach:** BioCNG is a niche sector, and developing countries have limited technical know-how. Also, replication is difficult and complex, as each project is different due to different feedstocks, product offtake and local conditions. A unique approach is required to create a conducive ecosystem that brings stakeholders together to leverage complementary strengths and ensure project sustainability. For example, formulating an ISP and its project partner (or SPV) can mitigate the barriers and risks associated with conventional project design and implementation.

- **Appropriate Business Model:** The BioCNG sector is unlike the wind and solar energy sectors, where the performance of the project can be ascertained based on the availability of the resource. The technology risk in BioCNG projects is high due to the variability in feedstock and operating conditions. An appropriate business model should be developed to create a mutually beneficial outcome for all key stakeholders, ensuring incentives for successful project performance and allocating and mitigating stakeholder risk appropriately. Investors in India regard the technology risk as critical but were reassured because the business model guaranteed the technology provider's performance through an incentive that guaranteed him a share of the equity.

- **Competitive Market and Quality Assurance:** In a competitive market such as India, project developers consider minimum project cost as a key principle. This often results in sub-standard plant and component quality, resulting in low plant life. Hence, it is important to promote technology adoption that is based on performance, long-term plant sustainability and economic, social, and environmental benefits. The business model developed was based on the performance of the project and the resulting payback of equity.

- **Market Volatility and Variability:** Apart from the biomass price variability risk, the BioCNG market competes with the natural gas market. Considering the impeding factors and unassured cash flows (payback), it increases the project financing cost and limits access to finance for the BioCNG projects. Carbon financing can be used to fill the differential in cash flow (revenues) due to biomass/BioCNG price variability and achieve reasonable investment returns. Further, innovative risk mitigation facilities can be used as an enabling mechanism to unlock financing from commercial banks and the private sector.

Other key lessons learned include the following.

- Developing a mapping methodology is crucial for identifying viable biomass projects in the long term

- Reducing the gap between the CNG price and the BioCNG notified uptake price can help mitigate project risk associated with biomass price variation

- Innovative business models can help de-risk biomass projects and achieve sustainable project performance and output

- The public sector plays a key role in the upstream of the BioCNG ecosystem, and deploying initial BioCNG projects can create an enabling ecosystem

- Interest rate subventions and loss/risk guarantees are effective mechanisms for mobilizing investment in BioCNG projects

- Revising (increasing) the BioCNG offtake price will reduce the net production cost of FOM and result in creating demand for FOM offtake

9.2 Case Study – Promoting BioCNG in Indonesia

a. Design Phase

Strategic Partnership and Stakeholder Engagement

The Government of Indonesia (GoI) has shown interest in the development of bioenergy as part of the national effort to reach net-zero emissions and transition to clean energy. It has requested GGGI support to conduct preliminary studies into the sector. After discussions with the GoI's Directorate General of New, Renewable Energy, and Energy Conservation (DGNRE), a BioCNG project in Indonesia was officially approved. GGGI developed the initiative under the direction of the Ministry of Energy and Mineral Resources (KESDM) and the National Development Planning Agency (Bappenas) and aims to harness palm oil waste, livestock manure and MSW for BioCNG production. GGGI commenced the project with a series of meetings with critical BioCNG actors, bringing together collective support for the government's goal of reducing emissions and enhancing renewable energy. This collaboration emphasizes fostering innovations, promoting public-private partnerships, and mobilizing resources for low-carbon energy. It also emphasizes sustainable finance and investment opportunities in clean power projects. GGGI has consolidated its cooperation efforts by working with different counterparts. For example, it has an MoU with Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) and ADM Capital Foundation to develop a technical, financial and economic assessment of BioCNG as an alternative to the diesel fuel used by the state electricity company (PLN). A copy of the MoU signed with key stakeholders for BioCNG projects in Indonesia is available in Appendix V.

Landscape Analysis – Gap and Barrier Analysis and Opportunities

GGGI conducted a thorough landscape analysis of BioCNG in Indonesia. The resulting study outlines key aspects of the country's BioCNG ecosystem, including policy, technology, financial and operational aspects. The analysis also reviewed Indonesia's macroeconomic environment and overall energy landscape. The analysis's report, "Landscape Analysis - BioCNG potential in Indonesia", provides a good reference point for understanding Indonesia's BioCNG sector and the opportunities and challenges it faces.

The report addresses a number of enabling challenges the BioCNG sector faces in Indonesia. Among others, these include the lack of a coherent regulatory framework, inadequate technical standards, inexplicit intra-governmental coordination, and competition from other fossil fuel substitutes.

The GGGI landscape analysis primarily focuses on two key enablers: the regulatory and legal landscapes and financial support. While the government has yet to produce a regulatory framework for BioCNG, Indonesia has many national level programs and policies relevant to creating the enabling environment BioCNG needs. The challenge is finding coherency among them, as the policy and regulation landscape is multisectoral and comprises inconsistent laws across different government levels. Government support through dedicated BioCNG policies is crucial for the emerging sector. Additionally, securing financial backing from local and international institutions is vital, requiring affordable loans, financial assistance, and subsidies to bolster Indonesian efforts.

Given the preceding context, several significant government achievements are worth noting. First, KESDM is spearheading initiatives to integrate biogas in co-firing palm oil mill boilers and piloting BioCNG factories to replace diesel in PLN's diesel power plants. Parallelly, Second, BAPPENAS is emphasizing the incorporation of biogas into national priority programs. Third, the Downstream Oil and Gas Regulatory Agency is developing regulatory standards that will promote integrating BioCNG with city gas networks.

Developing Indonesia's BioCNG sector faces a number of difficulties. Many of these may also apply to other countries developing their biogas industries. They include:

- Insufficient infrastructure, specifically in gas pipeline networks and BioCNG cylinder production
- Human resource limitations, especially in after-sales services and technical expertise
- Financial hurdles such as high investment costs, perceived high-risk perceptions by banks, and limited risk-reduction financial instruments

b. Implementation Phase

Policy Recommendations

GGGI has produced a report titled "Recommendations for the Regulatory Framework of Biomethane/BioCNG in Indonesia" that puts forward options for developing a biogas and BioCNG regulatory framework. The report is based on an earlier assessment of existing relevant statutes and directives and identifies the need for comprehensive legal and regulatory frameworks to govern the development and operation of biogas and BioCNG projects in Indonesia. Achieving this would entail revising existing regulations, developing standardized business classifications, defining national standards for BioCNG, addressing environmental considerations, and providing financial incentives to attract investors. The document proposes several effective strategies the government could consider using in amending or introducing laws that foster biogas and BioCNG growth in Indonesia, as discussed below.

Project Identification and Potential Business Models

A comprehensive market study was conducted to support the Government of Indonesia (GoI) in exploring the potential utilization of biowaste-to-biogas as an alternative renewable energy source in Indonesia. The study delves into the commercially viable business models of biowaste-to-biogas utilization, specifically BioCNG. Central and East Kalimantan provinces were selected as case studies. It is hoped they can provide insights into the opportunities for BioCNG utilization and the steps needed for implementation, both in these provinces as well as in a national context. This study uses several methodologies, including an analysis of the potential supply for BioCNG in Central and East Kalimantan provinces, scenario analysis for utilization (demand) to identify opportunities for BioCNG business models, financial/economic analysis to determine the most viable business models for development, marketing analysis using Bayesian statistical methods, and a gap analysis to identify the necessary steps to implement the recommended business model.

In the vast Indonesian landscape, Central and East Kalimantan stand out in the palm oil sector. Central Kalimantan, producing about 5.5 million tons, covers 1.34 million hectares, with 107 palm oil factories. Meanwhile, East Kalimantan encompasses around 0.95 million hectares with 75 palm oil mills. Considering their significance in the palm oil domain, these provinces were chosen for the study. The selected mills met key criteria: Roundtable on Sustainable Palm Oil certification, a management focus on renewable energy, and proximity within 100 km of urban areas. This selection ensures that the samples are representative, sustainable, and relevant to the region's energy goals.

Kalimantan's energy sector is undergoing a pivotal transformation characterized by a shift toward more sustainable sources, especially BioCNG. The energy derived from palm oil mills (POMs), coupled with the region's commitment to lessen external fuel dependencies, sets the foundation for this transition.

The financial analysis highlights that BioCNG provides the speediest payback when used as a replacement for Diesel Engine Power Plant (PLTD) fuel. This is followed by its potential in transportation and then for household and small-scale industrial applications. In contrast, the Bayesian analysis offers a different perspective. It proposes that the most viable areas of investment are households and small industries due to their high consumer acceptance levels, followed by transportation and PLTD. It is essential to note that this does not indicate conflicting recommendations; the Bayesian analysis uses pessimistic/conservative assumptions for its Diesel Power Plant calculations. All in all, BioCNG shows promise as a cost-effective household alternative to LPG. For its adoption for PLTD in Central and East Kalimantan, with current acceptance rates between 13% and 38%, the endeavor requires further studies for clearer insights.

In response to the paper's findings and to advance the BioCNG Program, GGGI has identified several key projects that hold significant potential. Table 4 provides an overview of these initiatives.

Recommendations:

Business Models and Investment Mobilization

Indonesia is still exploring business models and investment modalities suitable for developing a strong, viable BioCNG sector. GGGI has studied the potential for implementing biogas projects in Indonesia through a PPP approach. PPPs connect government or public sector entities with private sector companies to finance, design, implement and operate projects. The model recognizes that the traditional public sector-led approach to developing infrastructure faces limitations in the form of financial resources, technical expertise and operational efficiency. By leveraging the strengths and resources of both the public and private sectors, PPPs can overcome these limitations and deliver economically viable infrastructure development. GGGI's report on the potential for PPPs to operate biogas sector projects recognizes the inherent challenges a PPP approach faces while offering actionable advice on optimizing its role in expediting the sector's growth. For further information about the potential for PPPs in Indonesia's emerging BioCNG sector, refer to the GGGI report, "Public-Private Partnership for Biomethane Sector in Indonesia".

c. Scale-up Phase

According to the GGGI report, "Public-Private Partnership for Biomethane Sector in Indonesia", maximizing the contributions of the Biogas and Biomethane sectors will require strong infrastructure and well-defined investment strategies. The Public-

Private Partnership (PPP) model has proven effective in addressing the financial and developmental challenges within the energy industry, promoting cooperation between government entities and private enterprises. This report examines the role of PPPs in advancing the biogas and biomethane sectors in Indonesia. By analyzing the current state of these sectors, understanding the prevailing regulatory framework, and referencing successful PPP models from other fields, the challenges in implementing PPPs for biogas and biomethane initiatives in Indonesia become clear. The report also offers solutions to these challenges, underscoring the transformative potential of PPPs in propelling the biogas and biomethane industries forward.

Currently, the energy sector in Indonesia places significant emphasis on the PPP scheme as the country strives to diversify its energy sources, enhance energy access, and promote renewable energy development. Notably, within the oil and gas and renewable energy subsector, the Indonesian PPP Book includes two solicited gas distribution network projects. The PPP scheme aims to connect a target of 354,441 households through the construction of the Palembang gas grid and 307,749 households through the Batam gas grid, totaling 662,190 households. This number is significant, especially when considering that since 2009, the number of households connected by gas grids funded through the state budget has only reached 839,000 households. More details on the gas distribution network projects in the Indonesian PPP Book 2022, is outlined in Table 4.

The implementation of PPP schemes for biomethane-dedicated grid projects brings with it several challenges and gaps that need to be addressed. The gaps (mainly related to regulations, commercial economy, and environment aspects), hindering the effective execution of such schemes and deployment of biomethane, are as follows.

Regulations and Licensing:

- The PPP Book clubs new and renewable energy with oil and gas, which hampers the support needed for a sustainable energy transition.
- The ambiguity in delegating PPP authority to Regional Governments requires clarification.
- There is uncertainty in licensing, especially for location determination, land acquisition, and environmental permits.
- The Appointed Agency's commitment, particularly financial, needs reinforcement to ensure the long-term participation of palm oil mills.
- Government support, incentives, and guarantees specific to the biomethane gas grid sector remain undefined.
- While LPG conversion is regulated, the transition from LPG to gas through the network lacks a clear policy.
- Specific regulations governing the construction of biomethane grids are missing.

Commercial Economy:

- Significant investments are needed for gas grid projects, with the state budget no longer financing them. Government incentives could entice private entities to pitch in.
- Current gas prices challenge the commercial appeal of biomethane, necessitating a dedicated pricing strategy.

Table 4. Gas distribution network projects in the Indonesian PPP Book 2022

Sl No.	Project Name	Phase	CAPEX (in million USD)	OPEX (in million USD)	PJPK/ Owner	Sector	Province	City	Number of targeted household
1	Construction of the PPP household gas grid in Palembang	Preparation	228.6	26.06	MEMR	Oil & Gas and Renewable Energy including bioenergy	South Sumatera	Palembang	3,54,441
2	Construction of the PPP household gas grid in Palembang	Preparation	169.3	20.49	MEMR	Oil & Gas and Renewable Energy including bioenergy	Riau Islands	Batam	3,07,749

- Uncertainties about the long-term gas supply impact the project payback period.
- Post-Covid-19 budget reallocations slowed the city gas network development, potentially influencing decisions regarding biomethane grids.

Environment and Social:

- Gas grid projects have historically led to social conflicts in Indonesia, which might recur with biomethane grids.
- Challenges in licensing and land acquisitions emerge when gas pipelines intersect utilities managed by other entities.
- Pipe procurement processes, which might involve excavation and facility demolition, discourage some households from adopting the gas grid.
- Assuming palm oil mills mainly produce biomethane as a by-product, dedicated grid construction might meet operational reluctance.

A tailored regulatory framework for biomethane PPP projects is crucial, emphasizing streamlined approvals, transparency, and an investment-friendly environment. Effective public-private coordination ensures alignment with business goals. At the same time, financial incentives like subsidies and tax reliefs are needed to bolster commercial viability and attract private investment in city gas grid projects. Crafting a pricing strategy that benefits businesses and meets public affordability, especially for biomethane, is key. Challenges from uncertain long-term gas supplies influencing project paybacks must be addressed. Prioritizing biomethane-dedicated grids and innovative financing, such as blended finance models within PPPs, ensures financial sustainability. To tie loose ends, monitoring performance metrics of existing oil and gas PPPs is needed, as they are meant to allow the refining of strategies for biomethane projects.

d. Lessons Learned

- **Engagement of Stakeholders:** In successful program implementation, involving all stakeholders—policy makers, investors, technology providers, POMs (presumably project or program owners or managers), and offtakers—is crucial. Under the GGGI BioCNG Program, all the stakeholders, including policymakers, investors, technology providers, POMs, as well as offtakers, have been systematically engaged. The interventions under the program to build an enabling environment have played a key role in the overall development of the BioCNG ecosystem in Indonesia.
- **Building an Enabling Environment:** The key interventions of the program have played a significant role in fostering an environment conducive to the development of the BioCNG ecosystem in Indonesia and tailored to support the counterparts with their respective issues and gaps aptly.
- **Research and Studies:** The program conducted various studies addressing critical issues such as GHG inventory, carbon market research, calculation methodology of bioenergy potential from specific crops, environmental and social safeguards, and methane quantification from organic waste. These studies provided essential insights, highlighted gaps, and recommended strategies for improvement. GHG
- **Inventory and Carbon Market Research:** The paper focuses on the CO2 reductions tied to biogas plants and the potential of carbon markets, informed by both global cases and national rules. The 'Biogas Project Dilemma' graph reveals gaps in Indonesia's carbon market regulations. It emphasizes the need for clarity from the GoI on how private entities can contribute towards enhanced nationally determined contributions and the possible role of renewable energy projects in the nation's mandatory carbon market. Furthermore, while Article 6 emerges as a viable avenue to achieve ENDC objectives with external backing, the strategy for its adoption by the private sector remains a crucial question. To unravel these complexities, the research centered on two pivotal queries: the alignment of the international carbon market with Indonesia's framework and its implications for trading and revenue, and the financial feasibility of extending into BioCNG, considering associated costs.
- **Capacity Building:** To unlock the potential of BioCNG, it's crucial to strengthen the regulatory framework, set standards for raw materials, and implement risk mitigation strategies. Capacity-building building initiatives, including workshops and knowledge dissemination, were undertaken to educate decision-makers and entities involved in the biogas market. Recognizing this, GGGI initiated support in the form of information dissemination through several means. For instance, GGGI has held workshops aimed at honing the expertise of decision-makers in understanding processes, cutting-edge technologies, and the financial viability of BioCNG. The aim is to bolster the state's capacity to promote the biogas market, including BioCNG, within Indonesia such as RDI, IIF, and PT SMI to deepen their practical understanding of the sector GGGI has also contributed substantial insight into the content of World Intellectual Property Organization's Technology catalog for the treatment and valorizations of POME in Indonesia.

Other key lessons learned include the following:

- Establishing regulatory frameworks for BioCNG projects in Indonesia involves a cyclical process of reviewing and revising existing regulations, standardizing business classifications and defining national BioCNG standards
- Mainstreaming BioCNG in the national strategy for LPG substitution requires setting specific targets and policies that promote the entire BioCNG lifecycle, including production, distribution, and consumption

- Encouraging biogas and BioCNG investment requires providing clear legal and technical frameworks. Implementing the Standard Classification of Indonesian Business Fields (KBLI) 35203 and appointing oversight to the Department of Gas and New Renewable Energy (DGNRE) are vital steps
- Developing a quality benchmark for BioCNG involves creating a specific Indonesian National Standard (SNI) based on international criteria (ISO), best practices, and local input.
- Creating an enabling environment for BioCNG development through gas grid integration requires exploring benefits and committing to regulatory adjustments, infrastructure needs, and stakeholder engagement
- Ensuring the financial viability of bioenergy projects and safeguarding against investments in separate waste treatment plants involves developing a regulatory framework for the responsible and safe use of digestate on land

9.3 Case Study – Promoting BioCNG in Thailand

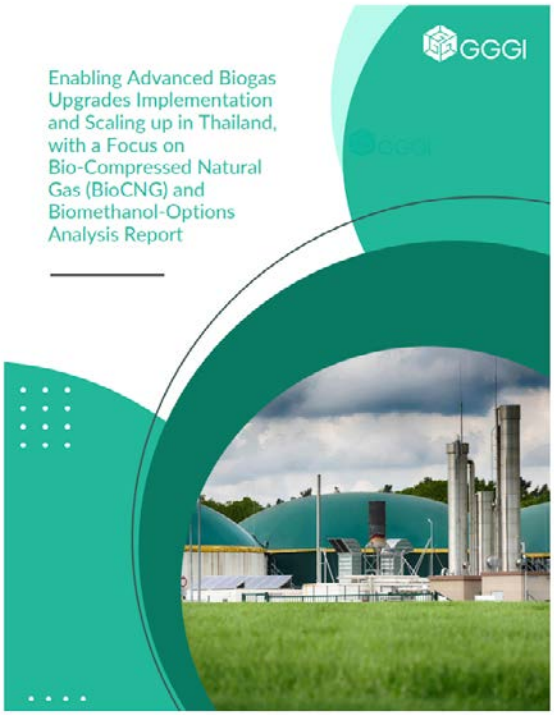
a. Design Phase

Strategic Partnership and Stakeholder Engagement

GGGI, under the BioCNG Program, partnered with the Energy Research and Development Institute, Chiang Mai University (ERDI-CMU) as a technical partner for conducting studies on the policy analysis, financial analysis, technology assessment, offtake strategy, potential plant assessments and selection, and policy recommendations for scaling up BioCNG in Thailand. GGGI is also engaged with PTT Public Company Limited (PTT), a state-owned energy firm, as an offtaker of BioCNG to replace LPG for industrial usage. GGGI provided policy recommendations and support to PTT to issue an offtake framework agreement of BioCNG for industrial usage. Such an offtake scheme would support all BioCNG firms in their efforts to build bankable projects.

In addition, GGGI, in partnership with the Office of Natural Resources and Environmental Policy and Planning (ONEP), organized a workshop, "Biomethane Current Affairs and Future Options in Supporting Green Energy Security of Thailand". The workshop set out to enhance the understanding of key stakeholders in Thailand on the status and potential of BioCNG and related biomethane applications. The event facilitated an open dialogue on the potential investments and policy adjustments needed to accelerate the sector further and raised awareness of the environmental, economic, and social benefits of advanced biogas-based applications. The next steps were discussed, including the policy and regulatory environment to facilitate sustainable BioCNG investment. The event was attended by participants from relevant government agencies, the private sector, academia, development partners, and NGOs.

Landscape Analysis – Gap and Barrier Analysis and Opportunities



GGGI prepared a sector landscape report titled "Information Memorandum Thailand BioCNG Program inception phase findings and discussions - Rethink biogas asset Recovery, Repurpose, Retrofit and Reuse in Thailand's Bio-Circular-Green economic framework". The report outlines the BioCNG, policies and programs, enablers, barriers, challenges and opportunities. GGGI also completed a report titled "Enabling Advanced Biogas Upgrades Implementation and Scaling up in Thailand, with a Focus on Bio Compressed Natural Gas (BioCNG) and Biomethanol Options Analysis". GGGI distributed these reports to relevant government agencies, the private sector, academia, development partners and NGOs.

Replacing fossil fuel-based CNG and LPG with BioCNG is economically and technically feasible, especially in the case of a biogas plant retrofit model. However, establishing BioCNG as a long-term viable option in the transportation sector might be fully align with the government's focus on promoting electric mobility. Guidance from the government on its stance regarding a sustainable transport fuel blend for the future would be greatly appreciated by the country's emerging BioCNG industry in the country. Mixing BioCNG with CNG could also be promoted, first at stations for natural gas vehicles (NGV) and possibly later with direct injection to the gas grid. PTT is the drawbridge for BioCNG injection and sale at NGV stations and through the grid. While the current economic environment is favorable to BioCNG, government interventions such as price guarantees could prove helpful in ensuring long-term price stability, reducing overall project risk and encouraging additional investments in BioCNG facilities.

Biomethanol is gaining traction globally, particularly in the shipping industry. Early analysis shows that producing biomethanol from biogas has strong potential in Thailand to replace currently imported fossil fuel-based methanol. The government could consider supporting this emerging sector with national energy and climate change policies or targets, together with the necessary regulatory framework. Establishing a pilot/demonstration plant is a key early step to kick-starting the biomethanol economy, which would likely require a direct subsidy. Following further detailed technical and financial studies, the government could consider involvement, for example, through the Encon fund, its agency for promoting efficient and renewable energy.

There is currently a lack of laws and mechanisms to enable injecting and blending BioCNG directly into natural gas pipelines. Developing these laws and mechanisms would assist the nascent BioCNG sector, as would developing green gas quality standards and inspection processes, technical guidelines to design injection points, and detailed injection procedures. The responsible government agencies could consider starting with a pilot process to assess feasibility and for capacity building. Studying and piloting green certification schemes would also assist the BioCNG and biomethanol markets become more dynamic and viable. These schemes are becoming common worldwide and enable willing companies to bear the higher cost of these green fuels to make their operations and image more eco-friendly. Green certification is especially useful as grid users cannot track their use of biomethane once injected and blended with natural gas in the pipelines. As an example, the UK has a well-functioning Green Gas Certification Scheme (GGCS) to enable the offtake of the 80 biomethane plants connected to the grid. In Denmark, it is expected that 30% of the gas in the gas grid will be green by 2023.

b. Implementation Phase

Policy Recommendations

GGGI recently facilitated a pilot offtake framework agreement between a BioCNG project developer and a state-owned oil and gas company. It recommended that the state enterprise consider announcing an open and transparent policy that encourages replacing fossil fuels such as LPG with BioCNG. Setting up a new offtake scheme would support all BioCNG companies in their efforts to build bankable projects.

Pre-feasibility, Feasibility Analysis and Project Identification

The pre-feasibility analysis identified 20 biogas plants with sizable excess biogas production capacity. This excess would manifest itself either in flaring of excess, unwanted or unproduced biogas. GGGI, in partnership with the Thai Biogas Trade Association, reviewed a list of over 40 utility-scale biogas plants facing biogas distribution and utilization issues. The issues mainly concerned the long-term biogas offtake, technology availability of feedstock, and private sector investment approvals, among other policy and regulatory challenges.

The GGGI BioCNG Program engaged with all the key stakeholders with support from the Thai biogas association community. A Request for Expressions of Interest (REOI) advertisement targeted plants flaring or underutilizing biogas, seeking their participation in developing a possible business plan for using excess biogas use that would focus on enriching and upgrading biogas. This advertisement helped build the initial longlist of 20 plants. The request for expressions of interest prepared for the Thailand BioCNG program (in Thai language) is provided in Figure 25. Request for expressions of interest to participate in Thailand BioCNG program (in Thai) provides a copy of the REOI.

Figure 25. Request for expressions of interest to participate in Thailand BioCNG program (in Thai)

Source: GGGI

The next step was to select 10 plants from the initial longlist of 20 plants with which to conduct a detailed questionnaire and assess their potential for upgrading technology. Initially, the methodology was to rank the plants by their excess production potential. However, in practice, things did not work out in this manner. Several plants were not contactable, and others did not wish to participate. Others were working on their own solutions and were confident of resolving their issues alone. Therefore, from the initial list, a subgroup of 10 were selected based on their willingness to participate in this program. Wherever it was possible to have a phone conversation with each of the 20 plants, a final list of 10 priority plants was obtained.

A questionnaire was sent to each plant after identifying 10 plants with excess biogas production potential and willingness to participate in this program. Most plants did not complete the questionnaire, so a phone interview was conducted to obtain the data. As part of analyzing and assessing the survey results, each biogas plant was assessed according to key criteria determining their suitability for upgrading. The criteria included biogas potential for excess biogas supply, proximity to other biogas plants, the availability and suitability of land for the upgrading facility, operator interest, proximity to markets for product distribution, and community support. The evaluation criteria are shown in Table 5.

Table 5. Evaluation criteria for biogas plant selection

Criteria / Description		Full score
1. Supply Potential		25
Excess biogas production potential	High (>12,000 m^3/day)	25
	Moderate (12000-6000 m^3/day)	15
	Low (<6000 m^3/day)	5
2. Cluster Analysis		10
Excess biogas production potential from plants within a 50 km radius	High (>12,000 m^3/day)	10
	Moderate (6000-12,000 m^3/day)	5
	Low (<6000 m^3/day)	0
3. Land Area		10
On site or adjacent area available for upgrading facilities	High (>10,000 m^2)	10
	Moderate (1000-10,000 m^2)	5
	Low (>1000 m^2)	0
4. Operator Interest		25
Interest of owner in upgrading to BioCNG	High (willing to co-invest)	25
	Moderate (willing to accept investment)	15
	Low (Not interested)	0
5. End market		20
Market location and logistic (range)	< 20 km	20
	20 – 50 km	15
	> 50 km	5
6. Policy support		10
Community support	High	10
	Moderate	5
	Low	0
Total		100

Final plant selection

GGGI conducted interviews with representatives from seven biogas plants, including five plants in Southern Thailand and two in Central Thailand, and scored their willingness and capacity to invest in BioCNG retrofitting. GGGI also conducted detailed pre-feasibility studies on BioCNG retrofitting investment based on data and information gathered from the interview, project consultant, and desk research. In addition to meeting plant representatives, GGGI liaised with other major stakeholders, including a state-owned oil and gas company with the potential to offtake BioCNG for transportation and substitution of LPG for industrial usage.

GGGI decided the most suitable approach was to produce BioCNG from existing excessive biogas to replace LPG for industrial heating. BioCNG for transportation was not considered for several reasons, including the low offtake price due to a government cap on the retail price for CNG used in transportation, the long distance between biogas plants and NGV stations, and the overall decline in CNG demand in the transportation sector. Overall, developing business and financial models for investing in BioCNG retrofitting for transportation is not productive, as the relevant government ministries do not presently support BioCNG for transportation.

In Thailand's Eastern Economic Corridor (EEC), industries currently use LPG for heating, creating a high demand from the industrial sector to switch from fossil fuel to renewable energy. While one of the two biogas plants in Central Thailand is not yet in operation due to issues with surrounding communities, another biogas plant in Chonburi was assessed as ready for BioCNG retrofitting investment. Chonburi is also close to several sizable industrial estates. GGGI assessed and approved the business and financial model for investing in BioCNG retrofitting the Chonburi biogas plant, proposing it as a best-in-class investment in late 2022.

Business Models and Investment Mobilization

A project developer is aiming to invest in developing a BioCNG retrofit project in Chonburi province. The project is expected to retrofit the existing biogas plant to produce BioCNG for selling to a state-owned oil and gas company. The BioCNG will be transported to industrial estates where existing customers of the state company will replace LPG for industrial heat generation. The technology for upgrading the biogas to BioCNG is Pressure Swing Adsorption. Figure 26 illustrates how BioCNG is produced and delivered to industrial estates.

There are no major regulatory hurdles or barriers preventing a factory from using BioCNG, and it depends purely on negotiations between the parties. Factors to consider include the upgrade requirements for existing burner equipment, the reliability of the BioCNG supply and the safety standards for handling and using BioCNG.

The most common fuel used for steam generation in Thailand is LPG. Thailand's Industrial demand for LPG is about 2,000 tons/day. Subject to small equipment modifications to allow combustion

with the different fuels, BioCNG can replace LPG for heating applications in industry. The factories and industrial estates that have previously replaced LPG with BioCNG kept the LPG system as a backup while installing a new nozzle and regulator for the BioCNG feed.

Given the economic constrains, the transportation distance from the BioCNG plant to the industrial plant must be less than 50 km. A fully loaded four-ton truck will use USD 0.065 (approximately 2.3 THB) to transport 1 kg of BioCNG within a 50 km range, comprising a round-trip of 100 km. Consequently, the only viable option is to produce BioCNG near industrial areas with a strong demand for natural gas or process heat.

Project Finance

The total capital expenditure (CAPEX) of 25 tons/day of BioCNG production is estimated to be about USD 5.55 million, pending the final technical design. The proposed project finance structure is expected to have a debt-to-equity ratio of 70/30 – approximately USD 3.88 million in debt financing and USD 1.67 million in equity financing. An outline of the financial structure of the project is presented Figure 27.

The selected project is relatively small in size and thus incurs high transaction costs. A standardized appraisal process could be developed that reduces transaction costs and pools similar types of investments under a unified financing facility. GGGI is currently working on creating a Thailand Circular Economy Financing

Figure 26. BioCNG as a replacement for LPG in industry

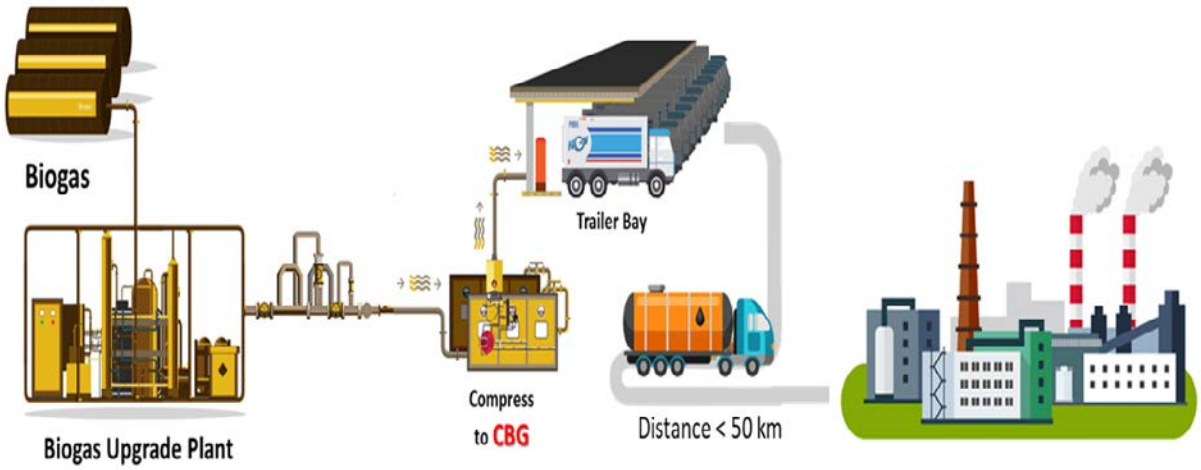
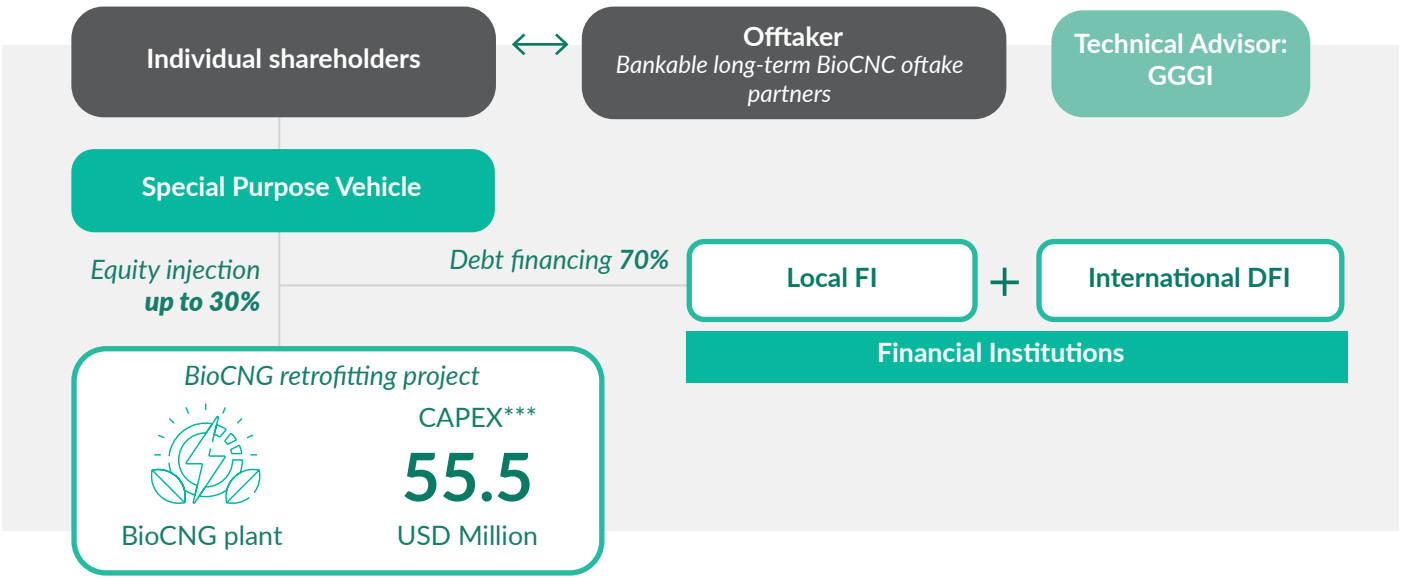


Figure 27. An outline of the financial structure of the project



Facility in partnership with the Green Climate Fund. Further support from international development finance institutions is needed in situations where the project developers are micro and small enterprises and have limited financial strength to provide the necessary collateral to mobilize investment and finance for potential projects.

c. Scale-up Phase

GGGI's assessment of Thailand's emerging BioCNG sector has identified two options likely suitable for scaling up the industry: using BioCNG as a CNG replacement in transportation and using BioCNG as an LPG replacement in industry. The demand trends for CNG and LPG in Thailand is highlighted in Table 6.

Option 1: BioCNG as a CNG Replacement in Transportation

This strategy uses BioCNG to power NGVs, replacing fossil methane. If used as a CNG replacement for transportation, there are two options: (i) build a separate BioCNG station and/or (ii) use an existing CNG station.

The cost of building a separate CNG station is more than USD 1.4 million (THB 50 million), meaning the second option is the only viable choice. PTT owns and franchises almost all CNG stations in Thailand. CNG stations that are connected to an underground gas pipeline would not be suitable as they lack the infrastructure to accommodate surface deliveries. This means the only suitable stations are those without a connection to a gas pipeline - CNG daughter stations. Another important factor is the transportation of BioCNG to the gas station. For economic reasons, the distance is limited to less than 50 km.

PTT offers a price of about USD 0.34 (THB 12.2) per kg for purchasing BioCNG in Central Thailand and about USD 0.42 (THB 15) per kg in Southern Thailand, according to August 2022 data. This pricing is too low for a feasible business case, even with the retrofit model. PTT uses a price-back approach to calculate the offtake price by subtracting the retail price, which is already low due to the government's transportation subsidy, from the PTT management cost/margin. Another key issue is that the CNG demand in transportation has declined from 3,241 tonnes per day in 2017 to 1,855 in 2020. Further, the demand will likely continue to drop due to a rising trend in electric vehicles. The feasibility of BioCNG for transportation depends on demand at gas stations, offtake price and transportation distance. All of these should be considered case-by-case.

Table 6. Demand for CNG and LPG in Thailand

Year	CNG demand in the transport sector (ton/day)	LPG total demand in Thailand (ton/day)	LPG Industrial demand in Thailand (ton/day)
2017	3,241	18,041	1,780
2018	2,933	19,190	1,882
2019	2,587	18,790	1,808
2020	1,855	16,370	1,676

Option 2: BioCNG as LPG Replacement in Industry

This strategy uses BioCNG as a replacement for LPG in heating applications in industry. It is slightly more cumbersome as BioCNG is not a direct replacement for LPG, which requires some minor modifications to the equipment to allow combustion with the different fuels. Since the fuel switch is not straightforward, there should be a price differential to encourage the changeover. Again, the transportation distance from the BioCNG plant to the industrial plant is restricted to within 50 km.

The price of BioCNG is expected to be lower per megajoule (MJ) than LPG. That is generally true and depends on the scale, as indicated in Table 7. If the price and quality of BioCNG are equivalent to LPG, it is worth exploring the demand from nearby factories. There are no regulatory hurdles or barriers to a factory using BioCNG. Based on discussions with PTT, there is a high demand from factories that are in the Eastern Economic Corridor's industrial zone, as the factories would like to switch to a clean fuel, particularly those operating in the export sector. Therefore,

it depends on the negotiations between the parties. The key considerations for this strategy include the proximity of customers to the BioCNG plant to keep transport costs low, attractive BioCNG pricing, constant and sufficient supply, safety standards for handling and using BioCNG, and the upgrade requirements for existing burner equipment.

Table 7. Heating value and price of LPG, NG and BioCNG in Thailand

Parameter	LPG	NG	BioCNG
Heating Value (MJ/kg)	45.50	61.52	50.0
Price (USD/kg)*	0.50	0.47	0.28 – 0.60
Price (USD/MJ)*	0.011	0.0076	.0055 – .012
2020	1,855	16,370	1,676

d. Lesson Learned

- **Strategic Partnership:** Where a state-owned enterprise operates as a sole offtaker of BioCNG for the transportation and industrial sector, establishing a strategic partnership is critical. Successful cases of BioCNG retrofitting could influence policies and regulatory interventions to support an open and transparent offtake framework of BioCNG across the country. Such an offtake framework would benefit all biogas companies in their efforts to build bankable BioCNG projects.

- **Awareness Raising:** It is important to increase the awareness of policy makers and the public of the importance of BioCNG in developing a circular green economy to achieve the country's energy security and nationally determined contributions (NDCs) to combating climate change. The Bio-Circular-Green Economy model focuses on the following sectors: agriculture and food, medical and wellness, bioenergy, bioproducts and biochemical, tourism and the creative economy.

- **Risk Management Approach:** BioCNG is considered a niche solution with a high offtake risk. Mitigating this risk is critical to building the confidence of project developers and financiers. Other key risks include uncertainties and availability concerns regarding feedstock, construction and technology risks, and community concerns over plant location. These risks could be mitigated via financial pre-feasibility studies based on off-peak production scenarios, performance guarantees with the EPCs, long-term offtake agreements, and environmental and social due diligence.

- **Appropriate Business Model:** BioCNG is unlike wind and solar, where the resulting energy can be offtaken by connection to the grid. Assessing the feasibility of a BioCNG business case must consider the costs of production and transportation, the offtake options and the price. For example, the BioCNG Program in Thailand is flexible in its approach, changing from BioCNG for the transportation sector to BioCNG to replace LPG in the industrial sector. This is because the offtake price of BioCNG for transportation is low, and the distance between BioCNG production plant and BioCNG station is too far. Other advanced biomethane upgrade pathways worth considering include biomethanol and biohydrogen.

- **Market Volatility and Variability:** Apart from biomass's price variability risk, the BioCNG market is prone to price volatility via its exposure to the natural gas market. Considering the impeding factors and unassured cash flows (payback), the project financing cost increases, limiting access to finance for the BioCNG projects. Carbon financing could fill the differential in cashflows caused by biomass/BioCNG's price variability and achieve reasonable investment returns. Further, using innovative risk mitigation facilities could unlock financing from commercial banks and the private sector.

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Appendices

Appendix I: Technical specification of BioCNG for Industrial applications

Sl No.	Characteristic	Requirement
1	Methane (CH4), minimum %	90%
2	Only Carbon Dioxide (CO_2), maximum %	4%
3	Carbon Dioxide (CO_2) + Nitrogen (N2) + Oxygen (O2), maximum %	10%
4	Oxygen (O2), maximum %	0.50%
5	Total sulfur (including H2S) mg/m3, maximum %	20 mg/m3
6	Moisture mg/m3, maximum %	5 mg/m3

Appendix II: BioCNG plant operation matrix template

A BioCNG plant operation matrix assists in mapping the supply of biomass from various sources at different periods of the year. This will help with planning the project's sustainable and continuous biomass supply. Further, the matrix also provides an indication of biogas and biomanure production potential.

Feedstock/Source	Quantity (in tonnes per day - TPD)												Total Feedstock (in tonnes per year)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Feedstock 1													
Feedstock 2													
Total available feedstock													
Additional feedstock (short-term sourcing/ storage)													
Total feedstock required (in TPD)													
Biogas Generation (in m3 per day)													
BioCNG Production (in TPD)													
FOM production (in TPD)													

Appendix III: Indicative Specification and Standards for 10 TPD BioCNG Plant

Sl. No.	Plant Components	Details
1.	Feed preparation and pre-treatment unit - for Storage and Pre-processing of raw material using mixer tanks	▪ Capacity of mixer tanks – 200 cum (2 X 100 cum) ▪ Feedstock processed – 30 to 50 ton (per batch) ▪ Daily Water Requirement – 500 cum (70% recycled from the operations and 30% top-up)
2.	Anaerobic Digester	▪ Total Digester Volume/Capacity –24,000 cum ▪ Volume/Capacity of one Digester- 6000 cum ▪ Number of Digesters – 4 ▪ Biogas Generation Rate – 1000 cum/hr
3.	Condensate Circuit	Chiller Rating and Capacity – 8 to 10 tons of refrigeration
4.	Fermentation Residue Buffering / Residue Storage Tank	Residue storage tank capacity - 1500 cum
5.	Gas Storage (in Balloon)	Volume/Capacity of Balloon – 2000 cum (~2 hr retention time)
6.	Biogas Purification and Upgradation Unit (membrane-based)	▪ Operating Pressure - 16 bar (ranges from 10-20 bar) ▪ Volumetric Flow Rate – 1500 cum/hr (for 16 hr operation)
7.	CO_2 Recovery Unit	Volumetric Flow Rate – 500 cum/hr
8.	BioCNG Compression and filling station (for cascade storage option)	▪ Compressor Volumetric Flow Rate - 1000 cum/hr ▪ Compressor outlet pressure – 250 bar ▪ Cascade Storage Capacity – 10,000 kg BioCNG
9.	BioCNG Compression and filling station (for grid injection option)	Compressor Volumetric Flow Rate – 1500 cum/hr Compressor Outlet Pressure ▪ Primary network (upstream) - up to 27 bar ▪ Secondary network (downstream) – 2 to 5 bar
10.	Mechanical solid liquid separator	Centrifuge/Decanter Capacity – 80 to 100 cum/hr
11.	Organic Fertilizer Unit	▪ Daily Production 60 tonnes ▪ Total Storage Capacity – 5000 to 6000 tonnes

Source: GGGI

Appendix V: Strategic Partnerships with Stakeholders

A. Memorandum of Understanding with Ministry of Petroleum and Natural Gas, Government of India, and Haryana Renewable Energy Development Agency and Investors, in India.

MEMORANDUM OF UNDERSTANDING

FOR

COMPRESSED BIOGAS (CBG) PLANTS

BETWEEN

MINISTRY OF PETROLEUM AND NATURAL GAS, GOVERNMENT OF INDIA,

AND

GLOBAL GREEN GROWTH INSTITUTE

MEMORANDUM OF UNDERSTANDING

BETWEEN

GLOBAL GREEN GROWTH INSTITUTE (GGGI)

AND

HARYANA RENEWABLE ENERGY DEVELOPMENT AGENCY (HAREDA)

ON

COOPERATION FOR IMPLEMENTATION OF COMPRESSED BIOGAS (CBG) PROGRAMME UNDER SUSTAINABLE ALTERNATIVE TOWARDS AFFORDABLE TRANSPORTATION (SATAT) INITIATIVE

Date: 17th May 2022

Memorandum of Understanding and Investment commitment with Indian Potash Limited and ReNew Power

MEMORANDUM OF UNDERSTANDING

BETWEEN

GLOBAL GREEN GROWTH INSTITUTE (GGGI)

AND

INDIAN POTASH LIMITED (IPL)

ON

COOPERATION TO SUPPORT IMPLEMENTATION OF BIOLOGICAL COMPRESSED NATURAL GAS (BIOCNG) PROJECTS IN INDIA

COOPERATION AGREEMENT

BETWEEN

GLOBAL GREEN GROWTH INSTITUTE (GGGI)

AND

RENEW POWER PRIVATE LIMITED

ON

SUPPORTING IMPLEMENTATION OF BIOLOGICAL COMPRESSED NATURAL GAS (BIOCNG) PROJECTS IN INDIA

B. Memorandum of Understanding signed with key stakeholders for BioCNG projects in Indonesia

MEMORANDUM OF UNDERSTANDING

BETWEEN

PT PLN (PERSERO)

GLOBAL GREEN GROWTH INSTITUTE (GGGI)

DEUTSCHE GESELLSCHAFT FÜR INTERNATIONALE ZUSAMMENARBEIT (GIZ) GMBH

THE ADM CAPITAL FOUNDATION LIMITED (ADMCF)

No. PLN [0002.MoU/HKM.02.01/C01000103/2022]
No. GGGI [ ]
No. GIZ [263/ExploRE/02/2022]
No. ADMCF [TLFF2202CBG]

REGARDING

JOINT STUDY OF COMPRESSED BIO GAS (CBG) PROJECT

This Memorandum of Understanding is made on **March 1, 2022,** day of **Tuesday, 01-03-2022,** in **Jakarta**, by and between:

I. **PT PLN (Persero)** an Limited Liability Company, duly incorporated under the laws of the Republic of Indonesia, having its domicile office in Trunojoyo Street Blok M I/135 Kebayoran Baru, Jakarta Selatan, 12160, in this Memorandum of Understanding represented by **Zainal Arifin** , as **Executive Vice President of Engineering and Technology Division** based on decree of SK Dir. 0148.K/SDM.02.02/DIR/2021 dated February 16th 2021, thereby acting for and on behalf of PT PLN (Persero), hereinafter referred to as **"PLN"**;

NOTA KESEPAHAMAN

ANTARA

PT PLN (PERSERO)

GLOBAL GREEN GROWTH INSTITUTE (GGGI)

DEUTSCHE GESELLSCHAFT FÜR INTERNATIONALE ZUSAMMENARBEIT (GIZ) GMBH

THE ADM CAPITAL FOUNDATION LIMITED (ADMCF)

No. PLN [0002.MoU/HKM.02.01/C01000103/2022]
No. GGGI [ ]
No. GIZ [263/ExploRE/02/2022]
No. ADMCF [TLFF2202CBG]

TENTANG

KAJIAN BERSAMA PROYEK *COMPRESSED BIO GAS* (CBG)

Nota Kesepahaman ini dibuat pada hari ini **Selasa**, tanggal **1**, bulan **Maret**, tahun **2022**, **01-03-2022**, di **Jakarta,** oleh dan antara:

I. **PT PLN (Persero)**, suatu Perseroan Terbatas yang didirikan berdasarkan hukum Republik Indonesia, berkedudukan di Jalan Trunojoyo Blok M I/135 Kebayoran Baru, Jakarta Selatan, 12160, dalam hal ini diwakili oleh **Zainal Arifin**, selaku **Executive Vice President Enjiniring dan Teknologi** berdasarkan SK Dir. 0148.K/SDM.02.02/DIR/2021 tanggal 16 Februari 2021, dalam hal ini bertindak untuk dan atas nama PT PLN (Persero), selanjutnya disebut sebagai **"PLN"**;

Paraf PLN Paraf GGGI Paraf GIZ Paraf ADMCF

Appendix IV: Techno-Economic Analysis (TEA) of a Green Field 10 TPD BioCNG plant

The techno-economic analysis for a 10 TPD BioCNG plant, along with financial assumptions is presented below. The key financial viability ratios such as payback period and return on investment (ROI) have been estimated to present the project's viability, sustainability, and profitability.

A. NPV, IRR, and payback period calculation sheet

			1	2	3	4	5	6	7	8	9	10
			2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Net Profit (PAT)	USD million		-	-	(-0.12)	0.33	0.51	0.61	0.71	0.79	0.87	0.94
Capex	USD million		(-3.72)	(-3.24)	-	-	-	-	-	-	-	-
Capex Subsidy	USD million		-	-	1.01	-	-	-	-	-	-	-
Change in Net working capital	USD million		-	-	(-0.32)	(-0.14)	(-0.02)	(-0.01)	(-0.01)	(-0.02)	(-0.02)	(-0.02)
Depreciation	USD million		-	-	0.91	0.78	0.67	0.57	0.49	0.42	0.36	0.31
Interest	USD million		-	-	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03
Total tax shield	USD million		-	-	-	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)	(-0.00)
Free Cash Flow to Firm (FCFF)	USD million		(-3.72)	(-3.24)	1.48	0.99	1.17	1.19	1.20	1.22	1.24	1.26
Terminal Value	USD million		-	-	-	-	-	-	-	-	-	-
Total	USD million		(-3.72)	(-3.24)	1.48	0.99	1.17	1.19	1.20	1.22	1.24	1.26
			-	-	-	-	-	-	-	-	-	-
Present Value of FCFF	USD million		(-3.38)	(-2.68)	1.11	0.68	0.73	0.67	0.62	0.57	0.52	0.48
Present Value of Terminal Value	USD million		-	-	-	-	-	-	-	-	-	-
TotalNPV			**(-3.38)**	**(-2.68)**	**1.11**	**0.68**	**0.73**	**0.67**	**0.62**	**0.57**	**0.52**	**0.48**
Cumulative			**(-3.72)**	**(-6.96)**	**(-5.48)**	**(-4.49)**	**(-3.32)**	**(-2.13)**	**(-0.92)**	**0.29**	**1.53**	**2.79**
Project NPV	**USD million**	**3**										
Project IRR	**%**	**16.01%**										
Project Payback	**Years**	**7.76**	-	-	-	-	-	-	-	7.76	-	-
PAT	USD million		-	-	(-0.12)	0.33	0.51	0.61	0.71	0.79	0.87	0.94
Subtract Equity Capex	USD million		(-3.72)	(-3.24)	-	-	-	-	-	-	-	-
Capex Subsidy	USD million		-	-	1.01	-	-	-	-	-	-	-
Add Depreciation	USD million		-	-	0.91	0.78	0.67	0.57	0.49	0.42	0.36	0.31
Change in Working Capital	USD million		-	-	(-0.32)	(-0.14)	(-0.02)	(-0.01)	(-0.01)	(-0.02)	(-0.02)	(-0.02)
Less repayment	USD million		-	-	-	-	-	-	-	-	-	-
Net Cash Flows	USD million		(-3.72)	(-3.24)	1.47	0.98	1.15	1.17	1.18	1.20	1.21	1.23
Terminal Value	USD million		-	-	-	-	-	-	-	-	-	-
Total Free cash flow to Equity Shareholders (FCFE)	USD million		(-3.72)	(-3.24)	1.47	0.98	1.15	1.17	1.18	1.20	1.21	1.23
Cashflow available for distribution to Project Equity			**-**	**-**	**1.47**	**0.98**	**1.15**	**1.17**	**1.18**	**1.20**	**1.21**	**1.23**
Cumulative			**(-3.72)**	**(-6.96)**	**(-5.49)**	**(-4.51)**	**(-3.36)**	**(-2.19)**	**(-1.01)**	**0.19**	**1.41**	**2.64**
Equity NPV	**In INR Lakhs**	**3**										
Payback Period		**7.84**										
Equity IRR	**%**	**15.76%**	-	-	-	-	-	-	-	7.84	-	-

** Diffrence in Equity IRR due working capital finance*

		11	12	13	14	15	16	17	18	19	20	21	22
		2032	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**
Net Profit (PAT)	USD million	1.00	1.07	1.11	1.17	1.22	1.26	1.31	1.36	1.40	1.49	1.53	1.57
Capex	USD million	-	-	-	-	-	-	-	-	-	-	-	-
Capex Subsidy	USD million	-	-	-	-	-	-	-	-	-	-	-	-
Change in Net working capital	USD million	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)
Depreciation	USD million	0.27	0.23	0.20	0.17	0.15	0.13	0.11	0.09	0.08	0.01	-	-
Interest	USD million	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04
Total tax shield	USD million	(-0.00)	(-0.00)	(-0.00)	(-0.01)	(-0.01)	(-0.01)	(-0.01)	(-0.01)	(-0.01)	(-0.01)	(-0.01)	(-0.01)
Free Cash Flow to Firm (FCFF)	USD million	1.28	1.30	1.32	1.34	1.37	1.40	1.43	1.46	1.49	1.51	1.54	1.58
Terminal Value	USD million	-	0.32	-	-	-	-	-	-	-	-	-	-
Total	USD million	1.28	1.63	1.32	1.34	1.37	1.40	1.43	1.46	1.49	1.51	1.54	1.58
		-	-	-	-	-	-	-	-	-	-	-	-
Present Value of FCFF	USD million	0.45	0.52	0.38	0.35	0.33	0.30	0.28	0.26	0.24	0.22	0.21	0.19
Present Value of Terminal Value	USD million	-	0.32	-	-	-	-	-	-	-	-	-	-
TotalNPV		**0.45**	**0.84**	**0.38**	**0.35**	**0.33**	**0.30**	**0.28**	**0.26**	**0.24**	**0.22**	**0.21**	**0.19**
Cumulative		**4.06**	**5.69**	**7.01**	**8.35**	**9.72**	**11.11**	**12.54**	**14.00**	**15.48**	**16.99**	**18.54**	**20.11**
Project NPV	**USD million**												
Project IRR	**%**												
Project Payback	**Years**	-	-	-	-	-	-	-	-	-	-	-	-
PAT	USD million	1.00	1.07	1.11	1.17	1.22	1.26	1.31	1.36	1.40	1.49	1.53	1.57
Subtract Equity Capex	USD million	-	-	-	-	-	-	-	-	-	-	-	-
Capex Subsidy	USD million	-	-	-	-	-	-	-	-	-	-	-	-
Add Depreciation	USD million	0.27	0.23	0.20	0.17	0.15	0.13	0.11	0.09	0.08	0.01	-	-
Change in Working Capital	USD million	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)
Less repayment	USD million	-	-	-	-	-	-	-	-	-	-	-	-
Net Cash Flows	USD million	1.26	1.28	1.29	1.32	1.34	1.37	1.40	1.43	1.46	1.48	1.51	1.55
Terminal Value	USD million	-	0.32	-	-	-	-	-	-	-	-	-	-
Total Free cash flow to Equity Shareholders (FCFE)	USD million	1.26	1.60	1.29	1.32	1.34	1.37	1.40	1.43	1.46	1.48	1.51	1.55
Cashflow available for distribution to Project Equity		**1.26**	**1.28**	**1.29**	**1.32**	**1.34**	**1.37**	**1.40**	**1.43**	**1.46**	**1.48**	**1.51**	**1.55**
Cumulative		**3.90**	**5.50**	**6.79**	**8.11**	**9.45**	**10.82**	**12.22**	**13.65**	**15.11**	**16.59**	**18.10**	**19.65**
Equity NPV	**In INR Lakhs**												
Payback Period													
Equity IRR	**%**	-	-	-	-	-	-	-	-	-	-	-	-

** Diffrence in Equity IRR due working capital finance*

B. Estimates of the Technical and Financial parameters

Project Details	
Particulars	**Figures**
Total Project Cost including Land (million USD)	6.96
Generation Capacity (max), TPD of BioCNG	10
Average Generation Capacity (at av. utilization - 85%), TPD of BioCNG	8.4
Generation Capacity (max), TPD of FOM	62
Plant Life, Years	20
Land Area for Plant, Acres	10
Land Cost, million USD	0.48
Av. Biomass Price (USD/tonnes)	15
Av. Biomass Requirement, tonnes/year	95,370
OPEX (without Biomass), as % of Revenue	8%
Mode of transportation of BioCNG	Pipeline
Pipeline network length (Kms)	10
Total Cost of Pipeline, USD million	0.7

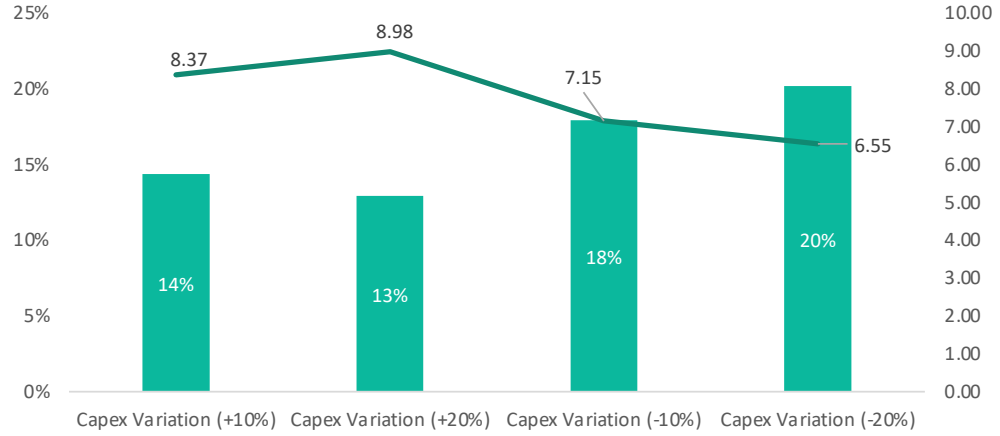
Financial Parameters	
Particulars	**Figures**
Financial Bank Guarantee (by ISP)	30%
Hurdle Rate	10%
Working Capital (60 Days), million USD	0.46 (2nd Year of operations)
Short-term Borrowing Share of WC	50 %
Short Term Interest Rate	9.5 %
Depreciation (Plant Asset & Machinery)	15%
Depreciation (Buildings)	10%
Corporate Taxation Rate (All Inclusive)	17.16%
Equity – Debt Ratio	1 : 0
Gross Profit (as % of Sales)	50%
Total Capital Turnover Ratio (Total Sales to Shareholder's Equity)	0.38
Profit After Tax (as % of Sales	12% (2nd year of operation) 17.2% in 3rd year

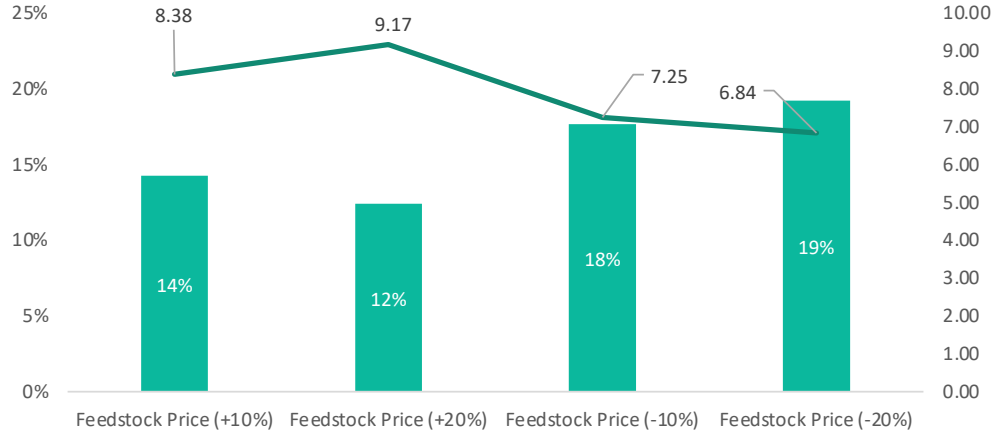
Revenue Streams	
Particulars	**Figures**
BioCNG, USD/Ton	795
FOM, USD/Ton	48

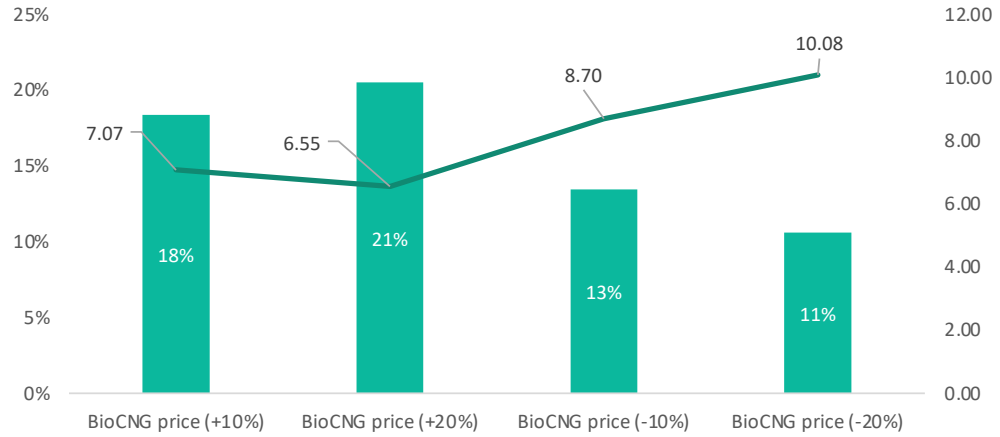
Viability Ratios	
Particulars	**Figures**
Payback Period, Years	7.76
Investor's Return on Investment (%)	16 %
NPV, million USD	3.06

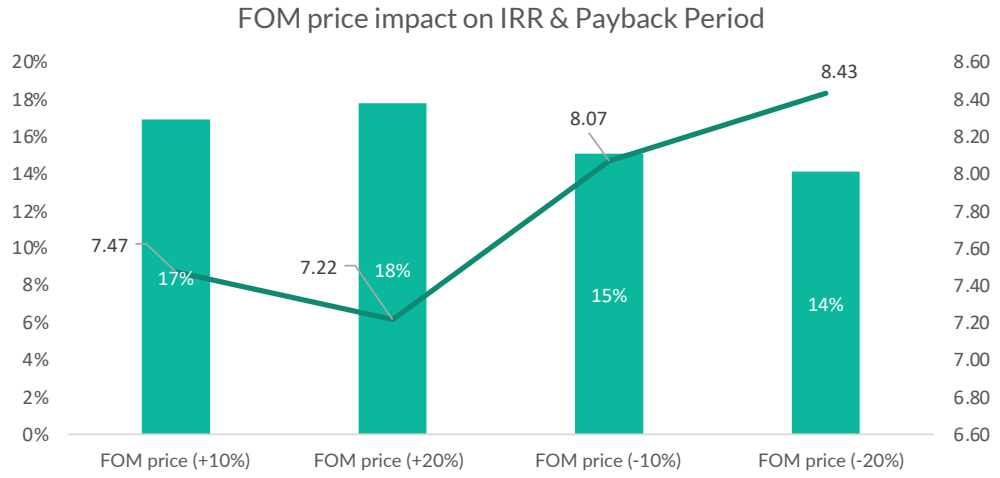
Returns to Shareholders – Post Payback	
Particulars	**Figures**
Share in Profit for Investor	78%
Annual Profit to Investor, million USD	0.94
RoI for Investor	26.3%
Share in Profit for ISP	22%
Annual Profit to ISP, million USD	0.27
RoI for ISP	25.8%

C. Sensitivity analysis based on variation in CAPEX, feedstock price, BioCNG price, and FOM price









Appendix VI: Summary of Terms to set up a BioCNG Plant (draft term sheet)

This term sheet ("Agreement") executed on [*] ("Agreement Date") summarizes the principal terms and conditions for the proposed BioCNG project i.e. [BioCNG project in "location"] ("Project") is executed between ["Company Name"] (hereinafter referred as the Integrated Solution Provider[1]) and ["Company Name"] (hereinafter referred as the investor[2]) (collectively referred as "Parties"). This Agreement has been entered to facilitate negotiations for the Project between the Parties and is an expression of intention only and does not constitute a legally binding agreement or create any legal right for any Party, except for Clause 10, 11, and 12 of this Agreement. which shall be legally binding on all Party hereto. The transaction contemplated is conditional on the required approvals by the management and board of directors of the Parties and the execution of final documentation and due diligence in a form that is satisfactory to each of the Parties.

The Parties shall conclude the following clauses under the Agreement

1. Proposed Project

Implementation (design, build, operate, and maintain) of a BioCNG project in "Plant Location"– based on the shared risk-return model. The Project will continuously process at least "plant capacity" tonnes of mixed feedstock to produce at least 8 tonnes of BioCNG on a daily basis and solid fermented organic manure (SFOM) and liquid fermented organic manure (LFOM) as a by-product, "SFOM Quantity" tonnes and "LFOM Quantity" million liters per annum, respectively.

2. Budgeted Project Cost

The estimated project cost is USD "Project Cost" Million, which includes the land cost, designing, technology, and equipment and machinery costs, among others. A detailed breakdown of the project costs is provided in the Separate Attachment.

a. Effective Date

The Effective Date shall be the date of signing of the "Design, EPC, and Operation Contract"[3] between investor/SPV and ISP.

b. Commercial Operation Date

The expected date for the commencement of the operation at the project level is "date". The final and agreed commercial operation date shall be given in the Design, EPC, and Operation Contract.

c. Contract Completion Date (for the Design, EPC, and Operation Contract)

The first date on which the following completion requirements shall be satisfied:

- The sustainable plant operation and performance, BioCNG and FOM production -quantity and quality, and Annual Revenue Target shall be satisfied in accordance with the Design, EPC, and Operation Contract.
- The relevant provisional/initial acceptance certificate shall be issued.
- The Plant and all associated infrastructure and utilities required for the Project shall be completed to the satisfaction of the Technical Adviser,[4] shall be accepted by the investor/SPV and functioning in accordance with the design and operating specifications set out in the Design, EPC, and Operation Contract.
- Meeting the technical and contractual requirements as per the offtake agreement of BioCNG and FOM
- 5 (five) years from the commercial operation starting date or the estimated payback period,[5] whichever is earlier.
- The Supply Contract(s), the Offtake Contract(s), and the Operations and Maintenance Contract(s) shall be unconditional and in full force and effect, and the Parties thereto shall be performing in accordance with their terms.
- All insurance required for the operating period shall be effective and in full force and effect, as certified by the Insurance Adviser.
- No Default [or force majeure] shall be continuing.

3. Proposed transaction

a. Investment

Subject to satisfactory technical, financial, business, and legal due diligence and its board approval, investor will make an investment

1 Integrated Solution Provider (ISP) is an entity or group of a group of entity, which shall have the entire technical and institution capacity to Design, Build, Operate, and Maintain the BioCNG project for long-term.

2 Investor is an entity providing equity and/or debt (upto 100%) as an investment for the designing and building of the BioCNG project

3 Design, EPC, and Operation Contract shall be the contract signed between ISP and the Investor/SPV, where ISP shall undertake the designing, erection, procurement, construction, commissioning, startup, and operation of the Project.

4 Technical Advisor shall be appointed by the Investor/SPV to independently evaluate the Project.

5 Estimated Payback Period is period between "Effective Date" and the date on which the 100 % Investment Amount to Investor and 100 % Financial Bank Guarantee to the ISP, is paid back, limited only to the principal amount (without the return on investment/opportunity cost for Investor/ISP).

(as equity and/or debt) of USD "amount" Million in the Project such that the shareholding or profit sharing in the Project shall be in the manner set out in the Clause 3.f. The Parties agree that the investment amount[6] shall be the basis for the execution of the Definitive Documentation.[7]

b. Financial Bank Guarantee and Coverage

ISP shall provide the financial bank guarantee[8] of USD "amount" Million (30 % of the Project Cost) in accordance with the provisions of Clause 3.g. Shared Risk-Return Approach. The financial bank guarantee shall reduce the year-on-year basis in proportion to the repayment of the investment amount, subject to meeting the plant performance and revenue targets[9] that are mutually agreed upon between the Parties. The shortfall in the annual revenue targets shall be bridged through the financial bank guarantee to achieve the target payback period for the Project, except for the provision mentioned in Clause 3.h. Deviation and Expectation.

c. Estimated Payback Period

ISP shall undertake the technical, financial, social, and market due diligence to estimate the project payback period of "Number" years. The deviation (increase) in the project payback period is not acceptable, except if it is due to any of the force majeure or mutually agreed upon between the Parties in writing.

d. Ownership and Shareholding

The investor shall institute a Special Purpose Vehicle (SPV) for the project. The investor shall have 100% shareholding in the SPV for the duration of the estimated payback period. During the post payback period, the ISP is entitled to a percentage of the shareholding in the SPV. The percentage will be estimated according to the calculation presented in "Separate Attachment" to this Agreement. The ISP shall have the first right of refusal in case the investor decides to dilute its shareholding in the SPV.

e. Profit/Revenue share

Once the Project generates a net profit, its first obligation is to pay back the investor, as a dividend, the amount she or he has invested. In case the financial bank guarantee is used to bridge the annual revenue targets, the net profit shall be used to repay the Financial Bank Guarantee Amount after 100% repayment of the investment amount to the investor. The net profit will be shared appropriately based on the shareholding of the investor and the ISP after the 100% repayment of the investment amount and the Financial Bank Guarantee Amount (in case forfeited).

f. Carbon Revenues

Any registered and validated emission reductions or mitigation outcomes (ERs/MOs) such as carbon credits, internationally transferred mitigation outcomes (ITMOs) or Voluntary Emission Reductions (VERs) generated[10] from the project can be traded using any carbon trading mechanism, including bilateral and voluntary mechanisms. The rights/title on ERs/MOs shall be with the investor/SPV. However, carbon revenues[11] (irrespective of ERs/MOs quantity and price) shall be considered as the project revenues and used to pay back the investment amount first. All formalities and actions related to the carbon revenues shall be the joint responsibility of the investor and the ISP.

g. Shared Risk-Return Approach and Risk Apportioned Shareholding

The financial bank guarantee from the ISP shall share the investment, operation, and performance risks associated with the Project and reduce the risks for the investor. The appropriate return against the risk shared through the financial bank guarantee shall be provisioned through suitable shareholding in the SPV after the estimated payback period. The basis for calculating the shareholding/profit sharing shall be outlined in a "Separate Attachment" to this Agreement.

h. Deviations and Exceptions

Meeting the revenue targets shall be the key to achieving the estimated payback. A deviation of up to 5% in the annual revenue target (greater than or equal to 95%) shall be allowed for two consecutive years only, and no financial bank guarantee shall be forfeited. Where the deviation is more than 5% for a year or up to 5% for more than two years, there should be no exception or deviation clause applicable.

i. Transaction Schedule

- Investment Amount shall be required to kick-start the Project

6 Investment Amount is the total amount of money to be invested into the Project by the investor, which is equal to 100% of the "Project Cost", in this case.

7 The Parties shall enter an erection, procurement, and commissioning (EPC) and Shared Risk Return Agreement ("ESRRA") for the furtherance of this Agreement and to inter alia incorporate the rights and obligations of the Investors and the ISP, within [90 (ninety)] days from the date of signing of this Agreement, which date may be mutually extended by the Parties. The ESRRA, the restated articles of association of the Parties and any other documents incidental to the Agreement shall be collectively referred to as "Definitive Documentation".

8 Financial Bank Guarantee – as an assurance that the payment is made to the Investor to cover the revenue differential, if the ISP does not able to achieve the target revenue of a year and resulting in delay of payback period. The terms of the guarantee shall be agreed between the Parties of the Agreement and approved by the issuing bank.

9 Annual Revenue Target is the revenues from the Project estimated by the ISP and basis for proposing the Estimated Payback Period. A year-wise estimated revenue targets for 20 years from the "Commercial Operation Date" shall be provided by the ISP in "Separate Attachment"

10 UNFCCC methodology of AMS-III.AO and AM0053 shall be adopted to estimate the CO2 eq. emission reduction potential and the carbon credits or ITMOs generated from the project.

11 Carbon Revenues shall be the revenues generated form trading the carbon credits or ITMOs under bilateral/cooperative approaches under Article 6.2 mechanism.

and award the contract to ISP.

- ISP shall submit the financial bank guarantee to receive the Letter of Allocation (LoA) from the investor.
- Signing of contract between investor and ISP on "Effective Date".
- Revenue realization after one year of commercial operation date
- Estimated Payback Period from the Effective Date.

4. Project Accounts

The SPV shall be required to establish and maintain project accounts[12] relating to Project cash flows, including the disbursement account and operating account, among others.

a. Disbursement Account[13]

The key function of the disbursement account is to undertake financial transactions (deposit/withdrawal) under the project prior to the commercial operation date, including the payments according to the design, EPC, and Operation Contract.

b. Operating Account

The key function of the operating account is to undertake financial transactions (deposit/withdrawal) after the commercial operation date, including project revenues, subsidies, and payments for the project operations, among others.

Parties may create any other accounts for specific functions as deemed suitable and mutually agreed.

5. Facilities

The investor shall secure the facilities for the Project. Technical and financial details for the facilities mentioned in this Clause are provided to account for the same in financial analysis and considered during project operation and maintenance.

a. Term Loan (if applicable)

- Amount of term Loan in USD "Amount" Million.
- Margin at any time prior to and on or after the commercial operation date, [] % per annum.
- Interest Rate shall be the applicable Margin plus (any period agreed between the SPV and the commercial bank/financing institution, generally six months) calculated based on the actual number of days elapsed in each Interest Period and a year of [360/365] days.
- Interest Period shall be "Number" Months or any other period agreed upon between the SPV and the commercial bank/financing institution.
- Commitment Fee shall be [] % per annum on the undrawn and uncancelled portion of the facility amount.
- Arrangement Fee shall be [] % of the total commitments under the term loan as at Financial Close.[14]
- Availability Period shall be from [the date of the Agreement] to the commercial operation date.
- Minimum amount of each utilization shall be in a minimum amount of USD "Amount" million for each utilization.
- Frequency of utilizations shall not be more than one utilization may be requested in each calendar [month]/[quarter].
- Purpose is to fund the payment of the project costs.
- Project Costs (as provided in Clause 2 of the Agreement) of developing, financing, constructing and commissioning the Project, including construction and commissioning costs, development costs and fees, pre-completion working capital, contingencies, financing costs during construction, development costs and fees, pre-completion working capital, contingencies, financing costs during construction,([initial funding of reserve accounts), costs of obtaining any required consents/permit/approval, operating costs up to the commercial operation date, insurance costs, tax, etc.

b. Working Capital

- Revolving [loan/credit] fund of USD "Amount" Million per Month, which may be utilized by way of drawing loans and issuing letters of credit.
- Interest Rate shall be the applicable Margin plus (any period agreed between the SPV and the commercial bank/financing institution, generally six months) calculated based on the actual number of days elapsed in each Interest Period and a year of [360/365] days.
- Interest Period shall be "Number" Months or any other period agreed between the SPV and the intercreditor agent.

12 This structure establishes one main account for the construction period (the Disbursement Account) and one main account for the operating period (the Operating Account). It may also be desirable to establish separate accounts for other defined revenue sources or purposes. Investor may also want to see accruals monthly in respect of operating expenses, in which case a separate operating expense account will be required.

13 This is the principal 'Construction Period' account. This is to monitor and understand the timing and make-up of construction period revenues and the timing for payment of construction period costs.

14 Financial Close is the date on which the term of financial transaction is signed.

- Commitment Fee shall be [] % per annum on the undrawn and uncancelled portion of the facility amount.
- Availability Period shall be from [the date of the Agreement] to the [Financial Completion Date]/ [Commercia Operation Date].
- Minimum Amount of each Utilization shall be in a minimum amount of USD "Amount" Million for each utilization.
- Frequency of utilizations shall not be more than the "number" (times) utilization may be requested in each calendar.
- Purpose is to fund the working capital requirements of the Project.

6. Operation and Maintenance

- SPV shall fund the service fees of the ISP for USD "Amount" Million per month (with mutually agreed annual escalation).
- The Fund shall be valid for the entire duration of the project life, i.e., an estimated life of 20 years.
- Purpose of the fund shall be to operate and maintain the plant optimally and sustainably, including the plant operation with best practices to produce a suitable quality of BioCNG, feedstock supply and quality management, and FOM on-site management.

7. Condition Precedent

- A complete legal and financial due diligence of the project proposal is to be completed to the satisfaction of the investors.
- The investor shall, in principle, approve the project proposal and undertake the due diligence of the ISP for the finalization of the partnership and contract.
- ISP shall in-principally agree to transfer (through sale) the land of "Number" acres to investor/SPV with (changed land use for commercial purpose) at USD "Amount" Million per acre, for the purpose of installing BioCNG project.
- Obtaining all regulatory permissions, approvals or consents required in relation to the investors' acquisition of the Equity Shares.
- Execution of the Definitive Documentation in form and substance in accordance with the agreed terms as enshrined in this Agreement, together with any other agreements and documents that may be deemed necessary by the Parties.
- Amendment of the Company's articles and memorandum of association and any existing shareholders' agreement to permit the partnership and all associated rights of this Proposed Transaction as provided for in the Definitive Documentation.
- No material adverse change shall have occurred in the business, financial condition, results of operations, or prospects of the Company and its subsidiaries.
- Any other conditions precedent that may be deemed necessary by the investor(s) pursuant to the due diligence conducted on the ISP or otherwise.

8. Development and Implementation Plan

a. Special Purpose Vehicle

Investor shall establish a Special Purpose Vehicle for the implementation of the Project in "Plant Location". SPV shall apply for the letter of intent to establish the BioCNG project from the gas marketing company or the city gas distribution entity.

b. Feedstock Supply Contract

ISP shall facilitate the signing of a triparted contract for the feedstock supply contract between SPV, ISP and the Biomass Aggregator/Supplier. ISP shall ensure the sustainable supply of the required quantity and quality of feedstock for continuous plant operation – as per the daily/weekly/ monthly supply schedule and recommended characteristics of each of the feedstock. And establishing standard operating procedures outlining the mechanism and measures to address the variation of up to 10% in biomass quality, specification, and price.

c. BioCNG and FOM Management and Offtake

ISP shall facilitate the engagement with the city gas distribution entity or gas marketing company to identify the suitable location for BioCNG injection into the grid and signing of the long-term commercial offtake agreement between the offtaker and SPV. ISP shall also engage relevant companies for the effective management and marketing of SFOM and liquid fermented organic manure (LFOM). ISP shall facilitate the signing of the contract for FOM offtake as well between the relevant company and SPV.

d. Project Design and Development

- The Design, EPC, and Operation Contract to ISP shall include the aspects related to project management, engineering, documentation, licensing, procurement, quality assurance, construction, compliance with laws, start-up, commissioning and testing, training, and supervision of operating and maintenance personnel, reports, capital spares, benchmark, metering equipment, etc.

- Clearly defined mechanisms for the performance guarantees, project completion, performance (Finance) guarantee liquidated damages, schedule requirements, commercial operation, delay liquidated damages, cap on delay liquidated damages, warranties on the equipment, etc.
- Outlining the milestones, payment schedule, and cash flow.
- Ensuring fulfillment of the environmental requirements, project security and insurance

9. Finalization of the definitive document incorporating the intent and essence of the provisions outlined in the Agreement Performance Parameters

a. Product Outputs as per specifications

ISP shall ensure the optimal operation of the Project to generate the specified quantity and quality of the BioCNG and FOM from the estimated feedstock inputs. ISP shall develop various operational mechanisms to mitigate the risks associated with the reasonable deviation[15] of feedstock quality and quantity.

b. Revenue Maximization from the sale of BioCNG and FOM

ISP may aim to maximize the revenue from the sale of BioCNG and FOM beyond the year-wise target recorded in the agreement. As a result, the payback period for the project will be shortened, the financial bank guarantee for the ISP will be released early, and profit share /shareholding in the project will be allocated early for the ISP. Revenue maximization from BioCNG sales shall be of the surplus generated from the project or volume of BioCNG available beyond the offtake agreement with the gas network/CGD entity.

The Parties will work towards achieving targets intended from the proposed transaction, including but not limited to the remittance of the investment amount, achieving expected payback, apportioned shared in the profit or shareholding to ISP and sustainable operation of the project within the timeframe specified in the ESRRA.

10. Management and Governance Structure

a. Management Committee

A Management Committee comprised of one representative from each Party shall manage and oversee the overall development process and keep the Parties apprised of all material aspects of and developments in connection with the Project.

If any Party withdraws from the Project or the Agreement in accordance with the terms of the Agreement, the representative of such withdrawn Party shall be permanently removed from the Management Committee.

b. Management Decisions

Till the equity payback period of the project, 100% of the decision-making power will be with the investor. Post equity payback, ISP will gain rights in management decisions in accordance with the profit share of the company.

The affirmative vote of all the representatives shall be required for decisions of the Management Committee with respect to the approval of amendments to the Development and Implementation Plan and with respect to the terms and conditions of the definitive document and any material agreement under the project. All decisions in respect of the project shall require the affirmative vote of the investor.

c. Management Meetings

Meetings of the Management Committee shall be held at least monthly/every two months/every three months unless otherwise decided by the Management Committee, and at such other times as may be determined by the Chairman of the Management Committee, upon at least 14 days' prior written notice to all Parties.

d. Investor Rights

It shall be agreed between the Parties that the investor shall have a veto vote in respect of management decisions.

11. Confidentiality

Each Party shall hold all confidential information in strict confidence and shall not disclose it to any third party except as may be reasonably required by such Party for the performance and fulfillment of its obligations under the agreement.

In addition, no Party shall release any press statement or any other public comment about the Project, the development process, the terms of the Agreement or the activities under the Agreement.

12. Costs and Expenses

All costs and expenses (including legal fees) reasonably incurred by the ISP in connection with the preparation, negotiation, printing, execution, implementation, translation, syndication, perfection and registration of the on account of documentation support upon request of investor/SPV, shall be paid by the investor promptly on demand, whether or not the Agreement is signed.

15 Reasonable Deviation in the quantity and quality that may not impact the BioCNG and FOM generation, shall be specified by the ISP.

13. Exclusivity

The Parties agree that following [60 (sixty)] days from the execution of this agreement, neither of the Parties, either by themselves or through any other person, shall approach or participate in any discussions or negotiations or solicit, discuss and/or encourage any financing arrangement under the agreement by any other person in any manner and will not provide any information relating to the agreement to any other potential investor and will clearly indicate to such other potential investors/party that this clause shall bind the Parties.

14. Governing Law and Jurisdiction

This Agreement shall be governed by India's Laws. Any disputes arising out of or in connection with the validity, interpretation or implementation of this Agreement shall be subject to the exclusive jurisdiction of the court in New Delhi.

15. Arbitration

In the event that any dispute, controversy or claim is unable to be resolved between the Parties within [30] [60] days after notice of such dispute, then such dispute may be referred to arbitration. All disputes hereunder shall be settled exclusively and finally by arbitration, irrespective of the magnitude thereof, the amount in dispute or whether such dispute would otherwise be considered justifiable or ripe for resolution by any court or arbitral tribunal. Each arbitration shall be governed by the arbitration rules of the Indian Laws. Each arbitration shall be held in New Delhi. The language of the arbitration shall be English.

16. Terms

The Agreement shall be effective as of the date of execution thereof and remain in effect until the earliest of (1) the withdrawal of all but one of the Parties, (2) the mutual agreement of the Parties to terminate the Agreement, and (3) 90 (ninety)] days from its execution of the Agreement, unless mutually extended by the Parties.

17. Notices

Any notices under this Agreement shall be in writing, in English and be delivered personally, by courier, registered airmail or by facsimile at the following address:

18. Timelines

It is the Parties' intention to complete the due diligence negotiations and sign the agreement on or before [date]. If the Parties cannot finalize the negotiations within this time period, the Parties may mutually agree to extend this period. If the Parties do not agree to extend this period, the Parties will be released from their obligations under this agreement.

19. Survival

The provisions relating to confidentiality, governing law and arbitration shall survive this Agreement.

The signature of this Agreement constitutes a confirmation of the firm interest of Parties to the transaction as outlined above and their readiness to cooperate, working in good faith towards the consummation of such a transaction.

Address of ISP
Address of Investor

The Global Green Growth Institute

19F Jeongdong Building, 21-15, Jeongdong-gil,
Jung-gu, Seoul, Korea 04518

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