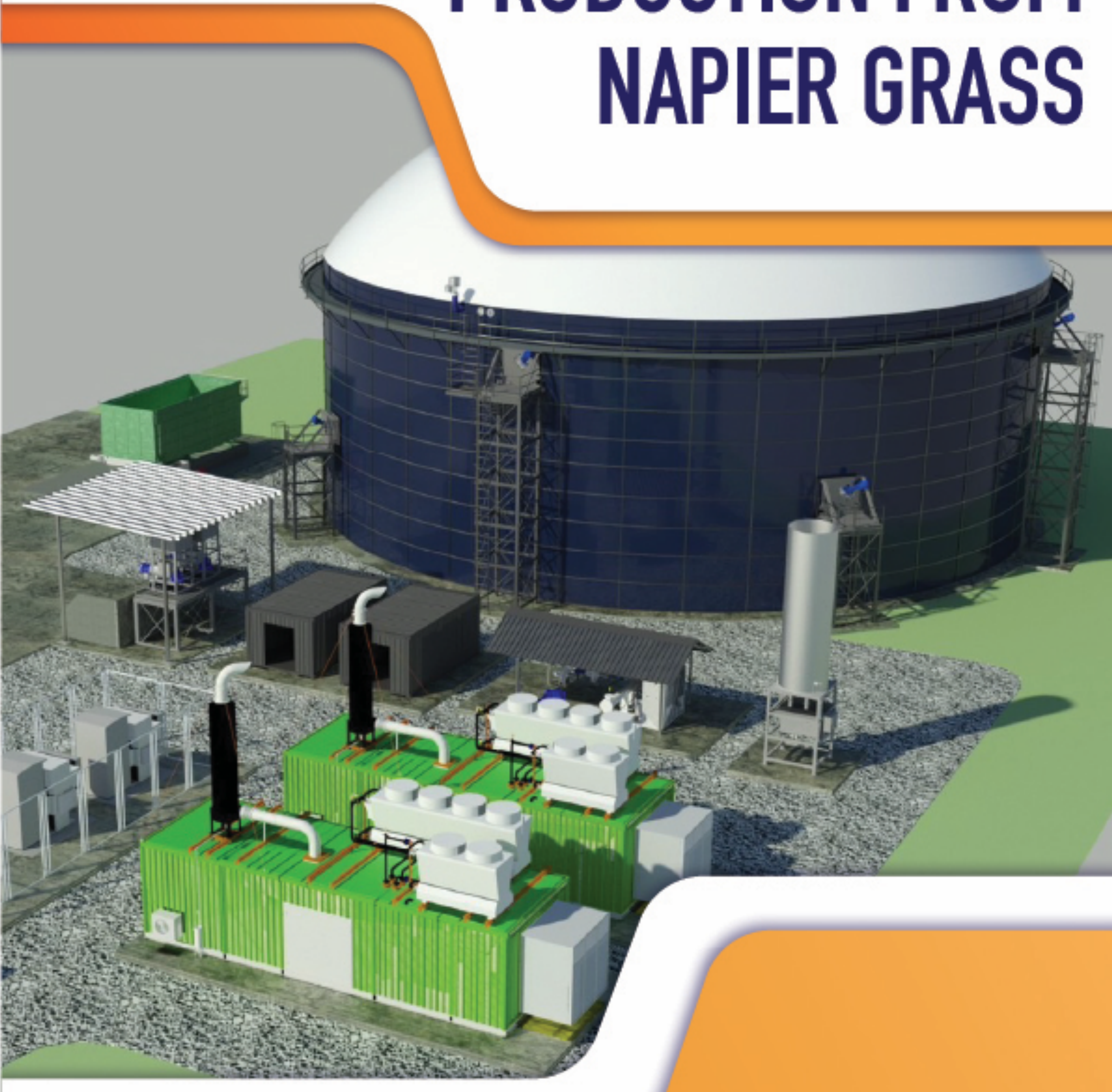
CO2 INNOVATION CO.,LTD

# ENHANCED BIOGAS PRODUCTION FROM NAPIER GRASS



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## Assumptions for this White paper:

- **Napier grass is harvested 5-6 times a year, yielding 70-80 tons/rai/year.**
- **The moisture content of the harvested grass is 67%.**
- **Dry Matter (DM) content is 33%, and Organic Dry Matter (ODM) content is 96%.**
- **Biogas yield is 690 m³/tonne ODM.**
- **Methane content in biogas is 55%.**
- **The land area planned for Napier grass cultivation is 3000 rai.**

## Disclaimer

**This white paper is based on a series of assumptions regarding the cultivation of Napier grass and its subsequent use in biogas production. The figures and projections presented herein rely on specific assumed values related to the yield of Napier grass, its moisture and organic dry matter content, biogas yield per tonne of ODM, and methane concentration within the produced biogas. These values are utilized to illustrate potential outcomes and should be considered as estimates that provide a framework for understanding the feasibility and implications of establishing a biogas production plant.**

**It is important to acknowledge that the actual results of such a project may vary significantly based on a range of factors including but not limited to the specific characteristics of the Napier grass used, variations in climate, soil conditions, cultivation practices, harvesting methods, and the efficiency of the biogas production process. Changes in any of these variables can influence the overall yield of Napier grass, the efficiency of biogas production, and the composition of the resulting biogas.**

**As such, while this white paper aims to provide a detailed and informed projection based on the given assumptions, it should not be taken as a definitive forecast. Stakeholders and interested parties are advised to conduct thorough due diligence and consider a range of potential scenarios and outcomes before making investment decisions or embarking on project implementation. Further research, field trials, and expert consultations are recommended to tailor the projections to the specific circumstances and parameters of the actual project site and Participating companies.**

# 1 EXECUTIVE SUMMARY

CO2 Innovation Company Limited has proposed to participating companies in Thailand to establish a biogas production plant utilizing Napier grass as the primary feedstock. This initiative plans to leverage 3000 rai of land owned by participating companies, aiming to create a sustainable energy source while aligning with environmental stewardship and renewable energy goals.

The proposal outlines the cultivation of Napier grass on the specified land, with an expected harvest frequency of 5-6 times per year, yielding an impressive 70-80 tons per rai annually. This equates to a total annual yield of 210,000 to 240,000 tons of Napier grass, considering the grass's moisture content of 70%, dry matter (DM) content of 33%, and organic dry matter (ODM) content of 96%. These factors are crucial for the subsequent biogas production process.

The biogas yield from this organic material is projected at 690 cubic meters per tonne of ODM, with the biogas comprising 55% methane. This yield signifies a substantial potential for renewable energy production.

This venture is not just a step towards sustainable energy but also a model for corporate environmental responsibility, demonstrating how industrial entities participating companies can utilize their resources to foster renewable energy projects. The establishment of the biogas plant represents a strategic move towards reducing carbon footprints, leveraging renewable resources.

In summary, the collaboration between CO2 Innovation Company Limited and Participating companies is poised to set a benchmark in renewable energy projects within Thailand, showcasing how agricultural innovation can be integrated with industrial operations to foster environmental sustainability and energy independence.

# 2 INTRODUCTION

In the quest for sustainable energy solutions, biogas production from renewable sources such as Napier grass has emerged as a promising avenue. CO2 Innovation Company Limited, in collaboration with participating companies, proposes to establish a state-of-the-art biogas production facility in Thailand, capitalizing on the robust biomass yield of Napier grass.

The technical foundation of this proposal is anchored in the substantial biomass potential of Napier grass, which is projected to yield 575 tonnes per day across the 3000 rai, culminating in an annual output of 209,875 tonnes. With a Dry Matter (DM) content of 33% and an Organic Dry Matter (ODM) content of 96%, the Napier grass harvested from this land is exceptionally suited for biogas production. The daily DM yield from this grass stands at 189.75 tonnes, which translates into an ODM yield of 182 tonnes per day.

The biogas yield from this ODM is estimated at a remarkable 690 cubic meters per tonne, resulting in a daily biogas production of 125,690 cubic meters. When considering the methane content of 55% in the biogas produced, the facility is expected to generate 69,130 cubic meters of biomethane per day, amounting to an impressive annual biogas volume of 45,876,996 cubic meters. This biomethane is a valuable resource for generating clean energy, contributing significantly to the reduction of greenhouse gas emissions and the reliance on fossil fuels.

Beyond biogas production, the facility underscores its commitment to sustainable practices by producing valuable byproducts in the form of solid and liquid fertilizers. Annually, the process is expected to yield approximately 37,075 tonnes of solid fertilizer with a moisture content of 75%, and 113,235 tonnes of liquid fertilizer with a moisture content of 95.7%. These byproducts further enhance the environmental benefits of the project, promoting a circular economy by returning essential nutrients to the soil and supporting agricultural productivity in the region.

This introduction sets the stage for a comprehensive exploration of the biogas production process, the scalability of Napier grass cultivation, and the impact of this project on both local energy supplies and broader environmental objectives.

# 3 RAW MATERIAL – NAPIER GRASS

Napier grass, or elephant grass, is a perennial, high-yielding forage grass emerging as a promising bioenergy crop due to its rapid growth and adaptability. It can tower up to 10-15 feet with the potential for 5-6 harvests per year, beginning four months after planting and then at two-month intervals, sustaining productivity for up to seven years. This robust plant is composed of 35-39% cellulose, 19-23% xylan, and 15-19% lignin, making it a lignocellulosic biomass favorable for bioenergy, with an impressive energy output-to-input ratio of 25:1. Napier grass's high biomass productivity, especially in certain hybrid varieties, is complemented by its ability to produce substantial amounts of biogas—90-110 cubic meters per tonne—due to its significant cellulose and xylan content that, upon hydrolysis, becomes an efficient substrate for methane-producing microbes.

Despite its high digestible organic matter content, pretreatment is often required to improve hydrolysis efficiency for biogas production. Moreover, co-digestion with materials such as cow dung or food waste has been shown to enhance biogas yield. Resilient to drought and with high water use efficiency, Napier grass can endure challenging growing conditions, though it is a warm-season crop that enters dormancy in colder months, which must be accounted for in year-round bioenergy production planning. Overall, Napier grass offers a sustainable and efficient option for bioenergy, presenting a valuable raw material for the development of renewable energy systems, although its growth cycle and pretreatment needs should be factored into its application.

## 3.1 RAW MATERIAL POTENTIAL

| Quantity (tonnes/day) | Quantity (tonnes/year) | DM content: (%) |
|---|---|---|
| 575 | 209875 | 33% |
| **ODM content (%)** | **DM quantity (tonne s/ day)** | **ODM quantity (tonnes / day)** |
| 96% | 189.75 | 182 |
| **Biogas yield ($m^3$ /tonneODM)** | **Biogas ($m^3$ /day)** | **Methane content (%)** |
| 690 | 125690 | 55% |
| **Biogas ($m^3$ / year)** | **Bio methane ($m^3$ / day)** | |
| 45,876,996 | 69130 | |

# 4 BIOGAS PLANT CHARACTERISTICS

| Characteristics | Values | Figures |
|---|---|---|
| Number of digesters | units | 5 |
| Digester | | |
| a) volume: | | |
| Work | sqm | 4005 |
| Overall | sqm | 4292 |
| b) Organic load | kgODM/ m3 | 9.65 |
| c) Hydraulic retention time (gross) | days | 35/33 |
| d) Overall dimensions of the digester | m | 27.0/7.5 |
| e) Temperature | deg C | 52 |

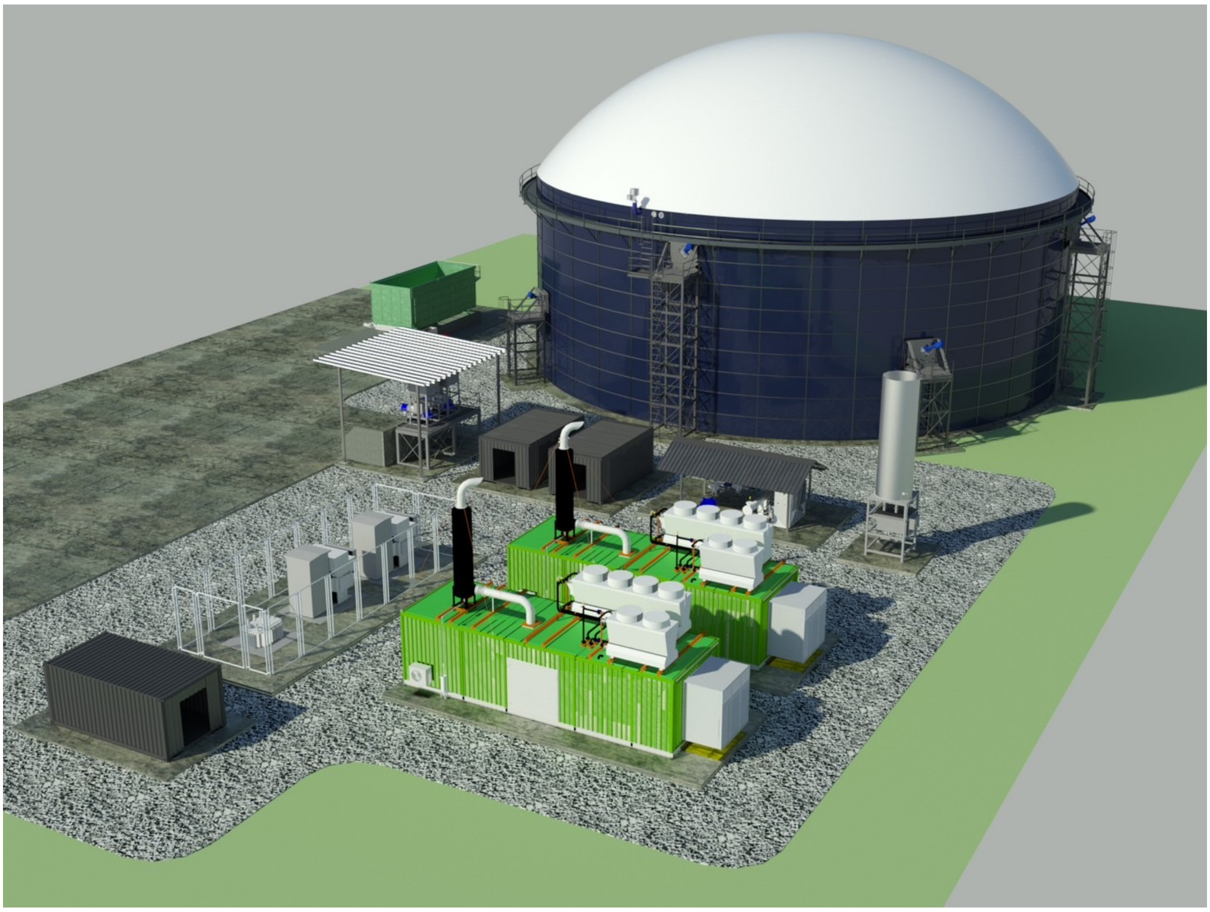
# 5 BIOGAS PLANT WORKING PRINCIPLE

The technology operates on a biochemical conversion principle, transforming organic substances from complex, high molecular weight entities into simpler, low molecular weight ones. This conversion begins with hydrolysis, a process breaking down organics into acids and alcohols, following the reaction where organic compounds and water yield C5H7NO2 and HCO3. These soluble compounds—organic acids and alcohols—undergo further transformation into gases such as methane (CH4) and carbon dioxide (CO2), as represented by the equation C5H7NO2 + HCO3 + H2O → CH4 + CO2 + NH4.

This biological conversion is a phased process occurring within an anaerobic setting, namely an oxygen-devoid tank or biological reactor. The initial phase is dominated by hydrolysis under the influence of acidogenic bacteria. Subsequently, primary organic materials are oxidized by hetero-acidogenic bacteria to yield acetate, CO2, and hydrogen. Concurrently, a portion of the organic matter is converted into C1 compounds (simple organic acids).

These intermediates serve as substrates for the third type of bacteria, the methanogens. Methanogenesis occurs through two distinct processes, A and B, each driven by different bacterial species. These processes facilitate the conversion of intermediates from the initial stages into methane (CH4), water (H2O), and carbon dioxide (CO2). Methanogenic bacteria are particularly sensitive to their environment; they demand strict anaerobic conditions and have a slower growth rate compared to acidogenic bacteria.

The rate and extent of the anaerobic fermentation are contingent upon the metabolic activity of the bacteria involved. Consequently, the chemical process in a biogas facility encompasses a hydrolysis stage, followed by oxidation and methanogenesis, all occurring sequentially within the same reactor.



# 6 TECHNOLOGICAL PROCESS OF BIOGAS PRODUCTION

Napier grass is conveyed to the biogas facility, where it is offloaded into handling equipment. This equipment, through the use of augers, systematically feeds the grass into the digesters. Inside the digesters, the biomass is heated to a maintained temperature of 52°C, essential for the thermophilic digestion process. To manage excess heat, especially during warmer seasons, the facility is outfitted with cooling systems.

Within these digesters, the biomass is stirred intermittently by vertical mixers to ensure uniform processing, with an average residency time of 31 days. Post-digestion, the biomass is pumped to a separation unit, where it is divided into solid and liquid bio-fertilizers. The solid fraction is relocated for storage, while the liquid is sent to a storage tank for liquid residues.

The generated biogas ascends and is channeled into an external gas holder via pipelines. This holder is shielded from environmental elements by a durable protective film, secured in place with a specialized system. To safeguard against excessive pressure, safety valves are installed on the digesters, set to release biogas into the atmosphere when pressures exceed 5 mbars.

The biogas, now collected in the gas holder, travels through pipelines to a cooling system that also eliminates condensate. It then reaches a compressor, where the pressure is increased to between 80-150 mbar to suit engine specifications. Following compression, the biogas is purified of hydrogen sulfide (H2S) through activated carbon filters. Subsequently, it enters a biogas upgrading unit where CO2 and other soluble gases are removed, resulting in a high-quality methane product that is approximately 99% pure, clean, and dry.

The entire operation is governed by an automated control system, with oversight conducted from a central control room. This room houses the central control unit, which allows for each module of the biogas plant to be operated in automatic or manual mode, and can be managed locally or remotely for efficiency and safety.

# 7 MAIN EQUIPMENT

## 7.1 SOLID FEEDER

Solid feeder machines have been proven in various situations. Solid feeder has the solid design, which guarantees a maximum functionality and less maintenance, combined to a low energy consumption. Because of the vertically oriented walls, there is no change for the material to get stuck or build bridges. The conveyor chains and the milling-unit allow continuous dosing by various types of materials. Furthermore, the material is loosened by this dosing process. The user is able to control the material flow up to 20m³/h or more, regarding to the own consumption of electrical power by the machine. In addition, the corrosion protection, wear resistance and high quality allow customers to use our product for a long period of time.

## 7.2 DIGESTER

The digester, designed as a cylindrical container to facilitate thorough mixing during fermentation, is constructed from cast-in-place reinforced concrete using sulfate-resistant cement. Its walls and base are 0.25 meters thick for robustness. At the heart of the digester is a central column topped with a capital. The top of the digester is sealed with a reinforced concrete slab.

Embedded within the walls and base of the tank are heating pipelines. These are critical for achieving and maintaining the elevated temperatures necessary for optimal thermophilic fermentation. To conserve heat and minimize energy use, the external surfaces of the digester—including the walls, top slab, and base—are insulated with 100 mm thick extruded polystyrene foam panels.

Above the heating elements, the digester's base and walls are further shielded with roll-type damp proofing to prevent moisture ingress. The external heat insulation is safeguarded against physical damage and pests by a cover of profiled metal sheets. Additionally, the base of the digester is constructed with a 1% gradient to ensure efficient processing and maintenance.

## 7.3 DIGESTER VERTICAL MIXER

Our mixers are crafted to ensure superior energy efficiency, featuring gear units and motors sourced from esteemed European providers, ensuring their longevity and reliability. Each component, including motors and gear units, can be supplied with ATEX certifications to meet safety standards in explosive atmospheres.

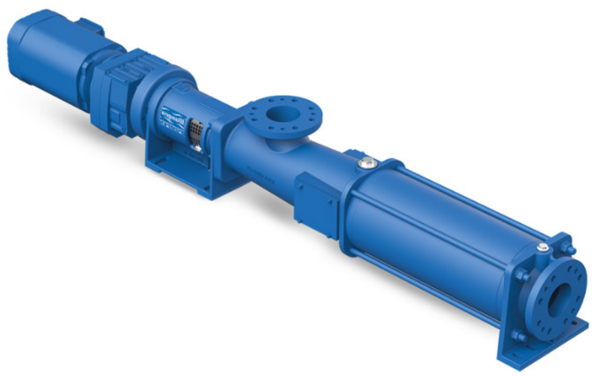
The agitators are specifically engineered to blend substrates with a solid content ranging between 13-18%. The design includes blades positioned at an ideal angle for effective mixing, while the mixer's external motor is installed on a dedicated support for enhanced stability and performance.

## 7.4 WINDOW WITH SPOTLIGHT

Inspection windows are designed for visual control of processes inside the fermenter. Spotlights were made in explosion-proof with automatic disconnection. Inspection windows are equipped with a cleaning washing system.

## 7.5 PUMP EQUIPMENT

Pumps are used to transport substrate to the equipment and facilities in the biogas plant and away. Biogas plant design allows to access easily to all pumps. Pumps are driven by helical geared motor. Stator has hopper inlet for optimum filling of the pumping chamber, wear-protected, robust universal joint with feeding screw, robust bearing pedestal with close-coupled drive and self-centering of the drive shaft. Pumps have modular design for high flexibility, low life-cycle-costs



## 7.6 SEPARATOR

The Press Screw Separator is adept for a wide range of applications, from agricultural uses to biogas and bioethanol production, thanks to its innovative design that efficiently separates substrates into solid and liquid components. Its adaptability stems from the ability to handle varying degrees of dry matter content, particularly excelling with thick liquids up to 20% dry matter. The device features slotted screens with an array of slot sizes and widths, accommodating a variety of small solids and fibrous materials. During operation, solids are filtered from the liquid through these slots, forming a layer that further refines the separation process, while the auger flights transport the solid residue to the discharge point. Continuous cleaning of the screen ensures consistent performance and formation of a new filtering layer. The screen's design prevents clogging, and the pressure within the screen compartment escalates from low to high, enhancing the separation process. An output regulator, adjustable through counter weights, allows for the customization of the solid's consistency, catering to specific requirements for storage, fertilization, or composting. Meanwhile, the separated liquid is conveniently expelled through a piping or hose system.


## 7.7 FILTRATE TANK

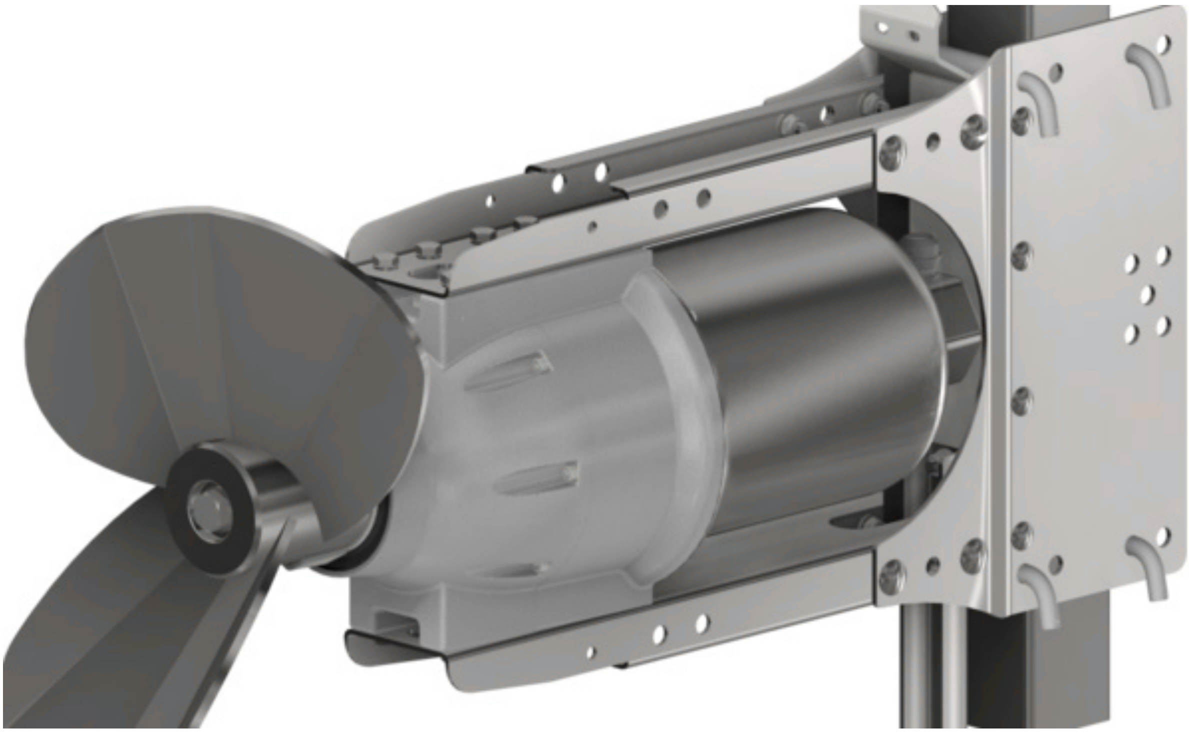
Reinforced concrete reservoir for reception of liquid kinds of raw materials. The reservoirs are equipped with level sensors and submersible agitators for mixing substrate.

## 7.8 SUBMERSIBLE MIXER

The submersible motor agitator is engineered for stirring renewable raw materials (RRM), liquid manure, and similar substances. It is an electro-motor-driven device designed for immersion in potentially explosive atmospheres classified as Ex zone 2, adhering to Directive 94/9 EC standards. This agitator can be attached to various sliding masts via its motor support, which is also equipped with a fixture for a hauling cable, allowing for vertical adjustments.

The motor support's 4-roller guidance system ensures smooth, frictionless vertical movement of the agitator, even when the pulling angle of the hauling cable is not perfectly vertical. It is standardized for a 100 x 100 mm square sliding mast but can adapt to an 80 x 80 mm mast with a simple roller adjustment. The cable's strain relief can be positioned either in line with the motor or at the top of the motor support, facilitating versatile installation options.

Constructed from durable materials, the geared motor is made from spheroidal graphite iron (GGG40) and is coated for protection, while the propeller is galvanized and the motor support is crafted from stainless steel. The agitator is designed as a water-tight monoblock unit that drives a three-vane propeller. Featuring a modular design, it combines a submersible electro-motor with a flange-mounted planetary gear and a bearing flange that holds the propeller. A conical shaft within the bearing flange, immersed in an oil bath and supported by two angular roller bearings, is sealed against the substrate with a mechanical seal, ensuring durability and efficient operation.



## 7.9 FILTRATE STORAGE TANK WITH GASHOLDER

Storage Tank is a tank of cylindrical form. It is built of cast-in-situ reinforced concrete based on sulphate-resistant cement with thickness of walls and bottom - 0,25m. The tank bottom has a slope 1%. The flexible gasholder is mounted above the tank. With or without a gasholder, the tank can be used as a storage for filtrate, manure or water. In the storage tank there are two submersible motor agitators serves for mixing renewable raw materials (RRM), liquid material and similar substrates.

## 7.10 BIOGAS DRYER AND COOLING

Biogas dryer and cooling are provided with special equipment as GAS COOLER and AIR-COOLED LIQUID CHILLER. Biogas plants thanks to an extensive range of dedicated Biogas solutions, low pressure heat exchangers, a comprehensive range of water chillers and RWD Dry Coolers. Designed as one-way shell-and-tube heat exchanger. Process gas inside of the tubes; cooling water in the shell. All parts in contact with the process gas made of stainless steel 316Ti or 316L; heat exchanger shell made of stainless steel/ Designed with gas outlet chamber outlet connection radial; inspection opening axial Official acceptance according to PED 2014/68/EU in accordance with ADMerkblätter and factory pressure test.

## 7.11 BIOGAS COMPRESSOR

Biogas blower is a device used to move gas and increase pressure thanks to a rotating impeller within a toroidal channel, so there is a progressive increase of energy. Blower is used to transporting biogas from gasholder storage to consumer (biogas upgrading plant in our case).

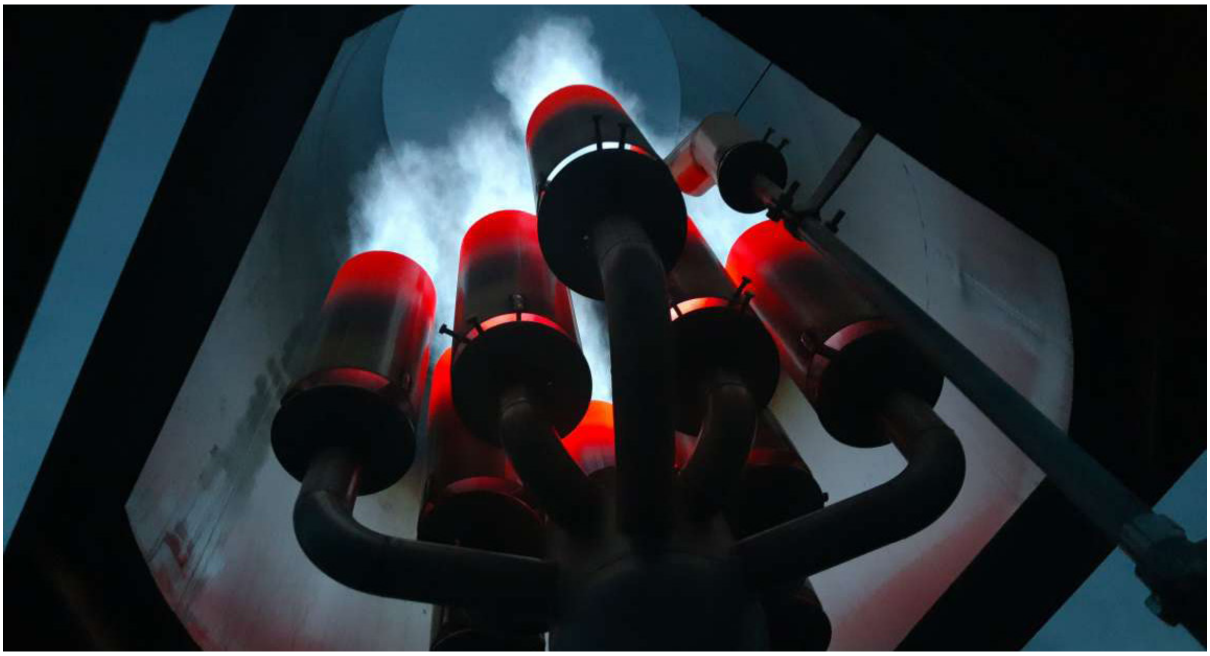

## 7.12 DESULPHURIZATION SYSTEM

The desulphurization system is a 3-step system. Stage 1 is adding Ferrum Hydroxide. Stage 2 - biological. Adding a certain portion of air to the fermenter. Air by special bacteria, converting H2S into S. After 1 and 2 steps the Sulphur concentration is 80 ppm. Stage 3 - activated charcoal filtration, as activated charcoal has the capability to absorb sulfur. After passing through activated charcoal filters, the sulfur concentration is reduced to 0 ppm.

## 7.13 FLARE

The flare is engineered to safely and efficiently burn off biogas from biogas plants when it cannot be utilized as an energy source, serving as a temporary or occasional solution for biogas disposal. It comprises a combustion system that includes a burner along with supplementary components. The burner operates on an injection principle, featuring a combustion nozzle equipped with an injector and an air supply regulation system, alongside a flame protection tube, fittings, and a burner management system.

Constructed from durable stainless steel, the biogas combustion apparatus includes a support structure that secures the burner and a vertically aligned socket. A control cabinet, affixed to the support structure, houses all necessary components for the oversight and management of the ignition and flame processes, ensuring the flare operates safely and effectively.



## 7.14 GAS ANALYZER

Gas analyzer - a measuring device to determine the qualitative and quantitative composition of the gas mixture. In a biogas plant's installed absorption gas analyzers, biogas mixture components are absorbed sequentially with various reagents. Automatic gas analyzers continuously measure any physical or physicochemical characteristics of the gas mixture or its individual components. Operation is based on physical methods of analysis, including auxiliary chemical
reactions.

## 7.15 WATER SUPPLYING AND SEWERAGE SYSTEM

Water supplying system provides biogas plant feed water, water for network circuits, the domestic water and fire safety systems. As used centrifugal single stage pumps as main pumping elements. These pumps are designed for pumping waste water, household / domestic water and sewage. Pressure Boosting Systems are designed for pure water pressure boosting in industrial plants. The booster comprises 2 to 3 (connected in parallel pumps) installed on a common base frame, and provided with all the necessary fittings.

## 7.16 HEATING SYSTEM

Heating equipment is using for biogas plant heating and for sustaining constant temperature in the fermenter. Heating equipment includes circulation pumps, heat exchanger, heating manifold and pipes. The heat from the boiler is transferred to the biogas plant by using heat exchanger, and then is pumped through of biogas plant by circulation pumps. A heat carrier prepares water with an additive of ethylene glycol. Inlet temperature in the fermenter is 60C, the outlet is 40C

## 7.17 DRY COOLER (COOLING SUBSTRATE SYSTEM)

Device is designed to cool the substrate to working temperature according to technological regime. When use high temperature substrate, there is a chance of uncontrolled heating. The cooler is connected to the heating pipes, heat exchangers and it will be activated if it is need.

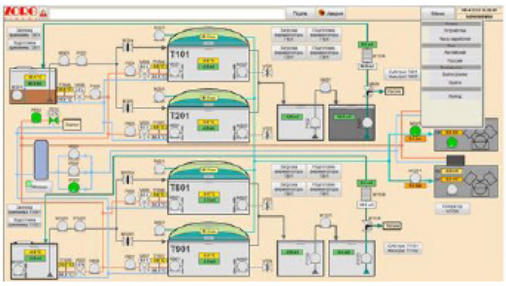
## 7.18 AUTOMATION AND ELECTRICAL EQUIPMENT

Process control equipment plays a crucial role in monitoring and managing the operations of the plant while also preventing damage. In emergency scenarios, such as a power outage, the equipment automatically shifts the biogas plant to safe operating conditions. It ensures that vital electric-powered components receive backup power.

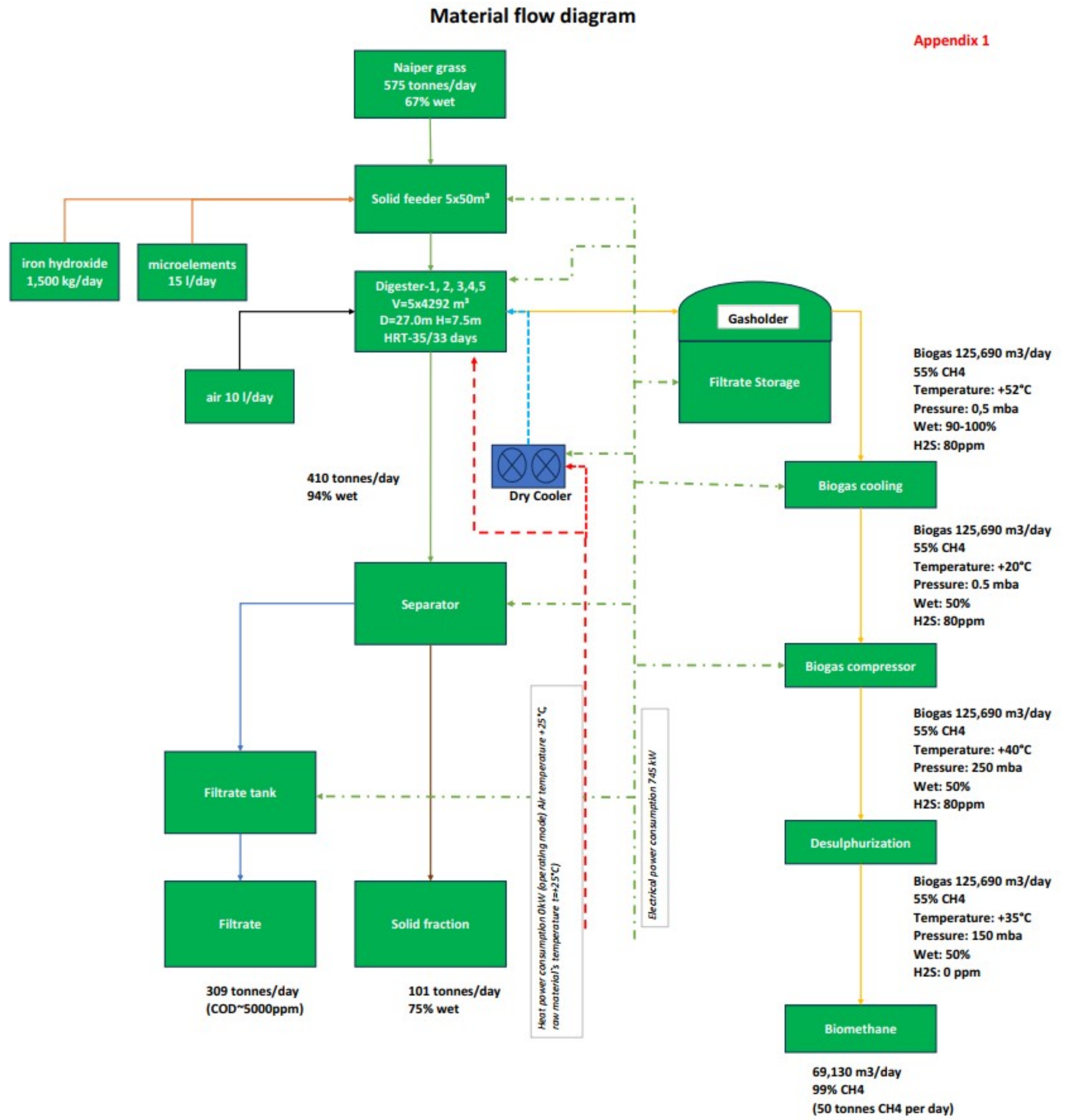
An advanced automatic system provides real-time monitoring of the plant, enabling immediate detection and correction of deviations. This ensures the plant operates efficiently, conserving resources and reducing costs, while also logging operational data for electronic records. The system includes a control cabinet equipped with sensors for monitoring various process parameters and controlling devices.

The cabinet's design is based on the Siemens industrial controller CPU315-DP2, utilizing the Simatic ET200S peripheral distribution system and an OP277 Touch operator panel with touch-sensitive controls. Communication is facilitated through PROFIBUS and MPI protocols with an RS-485 physical interface. The control software is developed using Simatic Step7.

The cabinet's modular design features a power box with a central processing unit and a front-end processor in the upper section. The Simatic ET2005 system is integrated with input-output units. The lower section contains interface relays and terminals for connecting actuating devices. A single operator can manage the entire plant, ensuring efficient and centralized control.


# 8 MATERIAL FLOW DIAGRAM



# 9 CONCLUSION

The proposal by CO2 Innovation Company Limited and participating companies to establish a biogas production facility in Thailand, utilizing Napier grass on 3000 rai of land, represents a significant step forward in sustainable energy generation. The project is poised to leverage the high biomass yield of Napier grass to produce substantial amounts of biogas and biomethane, aligning with environmental goals and supporting Thailand's energy policies.

The projected output of 209,875 tonnes of Napier grass annually, with its high DM and ODM content, underscores the potential for considerable biogas production, estimated at 45,876,996 cubic meters of biogas annually. This initiative not only contributes to reducing greenhouse gas emissions and decreasing fossil fuel dependency but also exemplifies a sustainable model of energy production that can be replicated in similar contexts.

Moreover, the production of solid and liquid fertilizers as byproducts showcases a commitment to a circular economy, where waste is minimized, and resources are reused, enhancing agricultural productivity in the surrounding areas.

In conclusion, this biogas production project is a testament to the innovative and eco-friendly approaches being adopted to meet future energy demands, demonstrating the potential of biomass as a renewable energy source while promoting environmental sustainability and economic viability in the region.