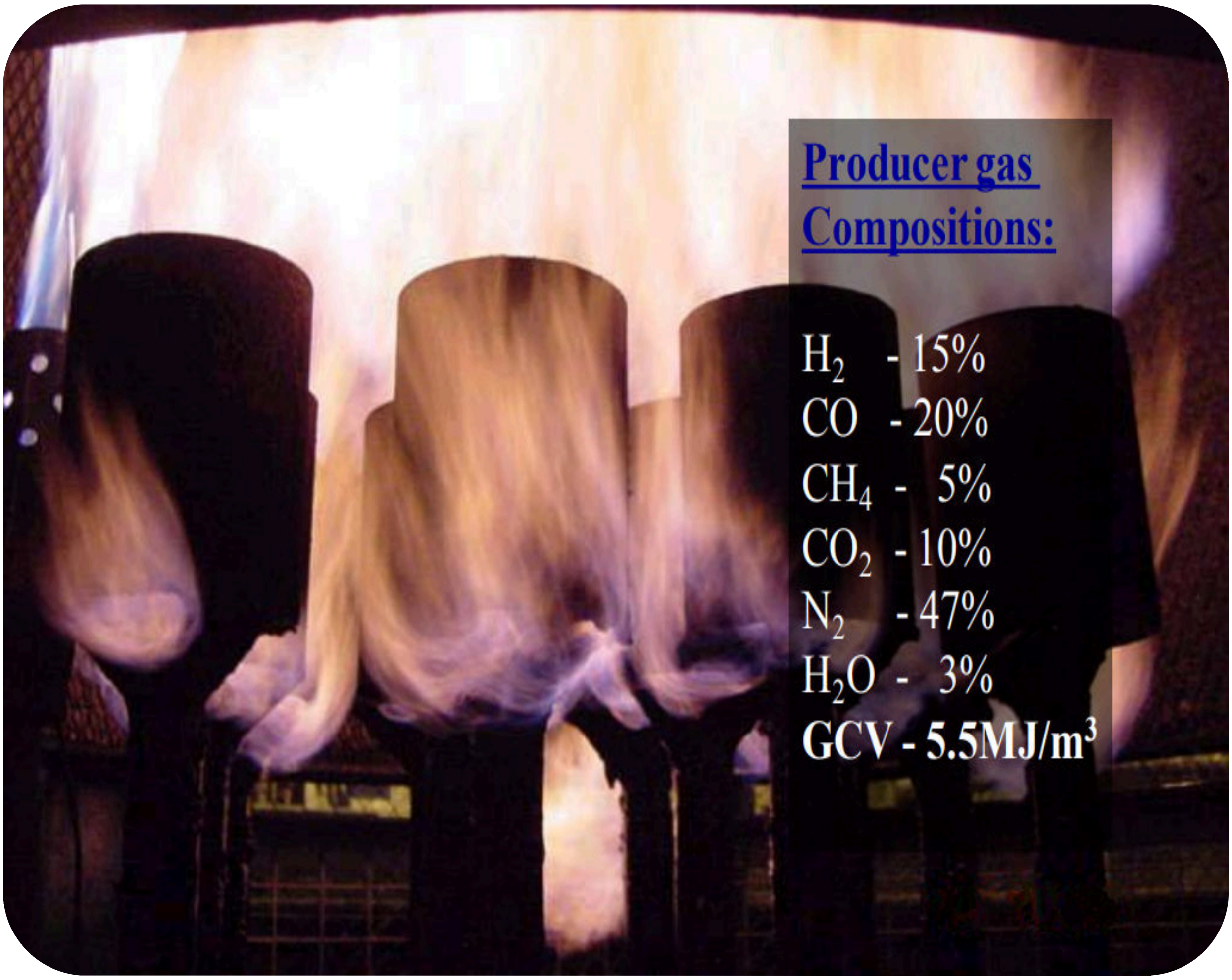


# BiMaGAS® POWER PLANT

## BIOMASS GASIFICATION POWER PLANT

# BASIC APPROACHES

The fuels to be used at the BiMaGAS® **Power Plant** - Gasification Power Plant include waste masses containing carbon and hydrogen, RDF, biomass, and dry sludge from wastewater treatment plants, which can be used separately or in a defined mixture.

BiMaGAS® **Gasification and Power Plant** is classified under renewable energy production, utilizing waste fuels as raw materials, and is presented as a fully environmentally friendly solution in terms of flue gas emissions. The following key features related to flue gas emissions emphasize the rationale and importance of this process:

1) A smaller volume of flue gas is produced.
2) There are no **furans** or **dioxins** in the flue gases, as the gasification process does not technically allow the production of these highly polluting and hazardous compounds.
3) Due to the lower and **appropriate** temperature parameters, much less NOx is generated.
4) SOx and NOx emissions in the flue gases are reduced to a maximum level using simple and safe solutions.
5) As a result of the above parameters, compared to the combustion process, operational costs are significantly lower.

In the context of **Urban Wastewater Treatment Plants**, the beneficial, economical, and environmentally compliant disposal of excess sludge remains a primary problem for these facilities. Another major issue is the necessity of eliminating odors produced in certain parts of these plants.

BiMaGAS® **Power Plant** is an environmentally friendly thermal process that can provide integrated solutions to both of these critical issues. **By disposing of 90% of sludge in urban WWTPs and generating electricity, the odor elimination problems of the treatment plants can also be addressed.**

The air needed for the BiMaGAS® energy process can be drawn from the odor-producing sections of the treatment plants, simultaneously enabling odor removal through **Thermal Oxidation**.

For the successful performance of the BiMaGAS® **GASIFICATION POWER PLANT**, it is sufficient for the waste fuel mixture, consisting of **85% dry sludge** and defined waste fuel, to have a minimum lower heating value of **15 MJ/kg**.

ISO 9001:2015 ISO 14001:2015

ISO 45001:2018

At the BiMaGAS® Power Plant, both **electrical energy and thermal energy** are produced. The **thermal energy** generated is utilized in the drying processes of WWTP sludge and/or other raw fuels that are not sufficiently dry. In facilities where there is no drying requirement, the thermal energy is used for greenhouses, swimming pools, and domestic heating needs.

**Endemic** holds ISO 9001:2015, ISO 14001:2015, ISO 45001:2018, ISO 10002:2018 and CE certifications as one of its additional steps in providing its customers with the best customer support and a high-quality product.

BiMaGAS® **Power Plant** are delivered in accordance with EU-fluegas emission directives, thermal units (EU framework directive for waste75/442/EC, EU directive on waste99/31/EC and amendments, EU "waste catalogue" directive for waste incineration2000/76/EC) and the EC Machinery Directive and welded according to European standards.

# THERMAL PROCESS COMPARISONS AND THE GASIFICATION METHOD

## 1. Reasons for Selecting the Gasification Process

As can be seen in the tables below, WWTP sludge, RDF, and other waste masses or mixtures of these waste masses can be used as fuel for three thermal processes: **Pyrolysis, Gasification, and Combustion**.

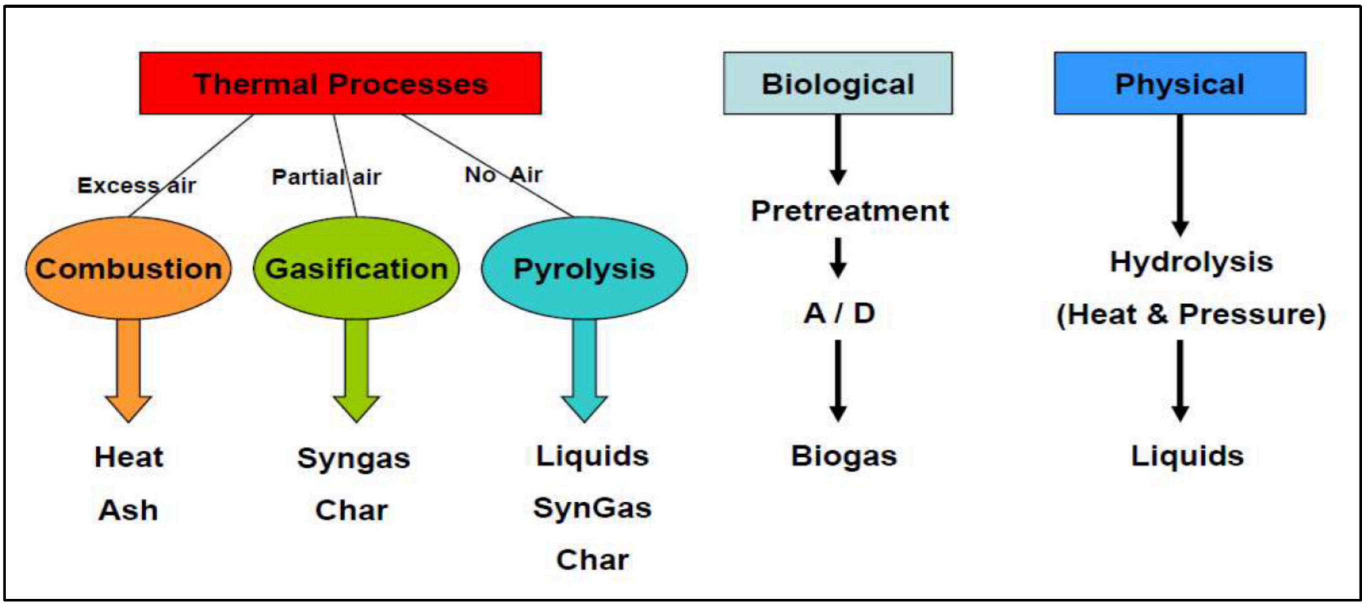


*Figure 1. Conversion Pathways of Sludge and waste biomass*

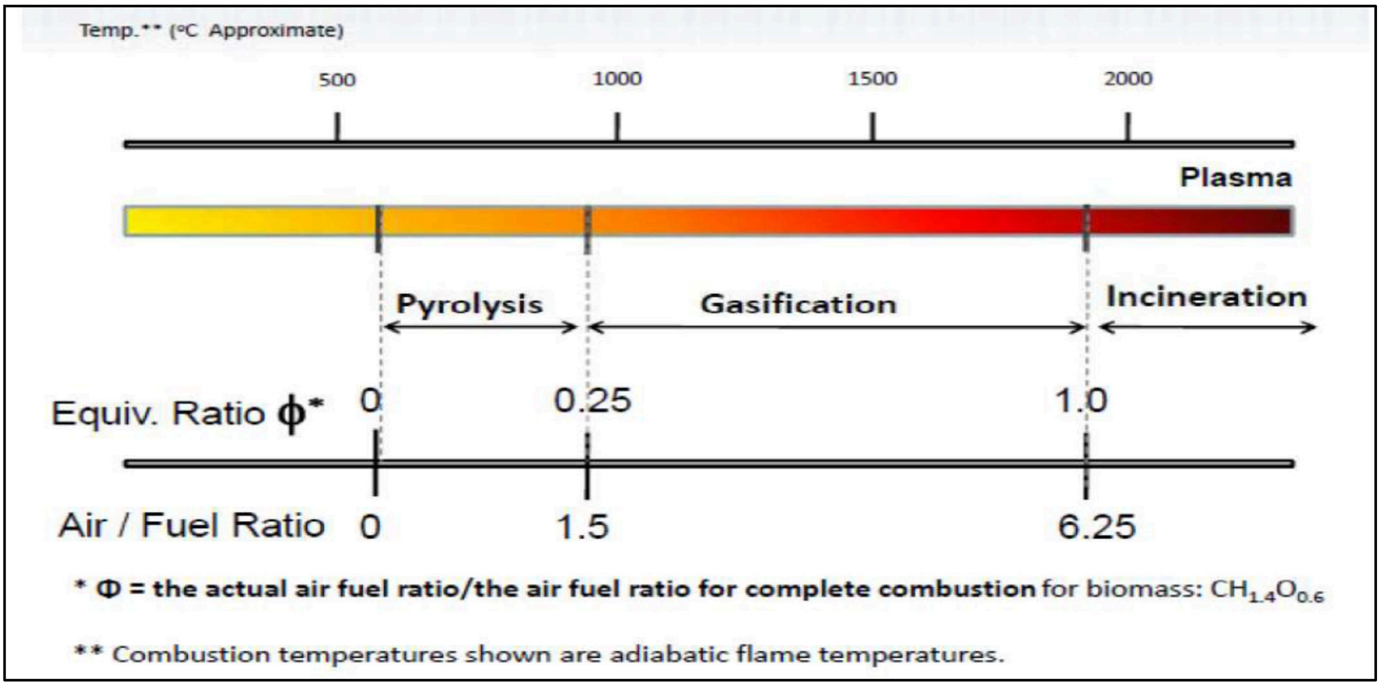


*Figure 2. Temperature and Air/Oxygen Ratio Management: Pyrolysis, Gasification, and Combustion*

For these Thermal Systems, the following assessments and comparisons can be made based on the current applications, operational experiences, and R&D studies:

**The pyrolysis system**; while theoretically superior, requires very high operational precision in industrial designs and faces serious operational problems in maintaining process stability.

**The combustion system**; operates with high excess air coefficients, resulting in significantly high amounts of flue gas emitted.

Due to the high combustion temperatures, **dioxins**, **furans**, and **NOx** pollutant parameters are formed, necessitating advanced and costly flue gas cleaning technologies. This process generates solid waste slag/ash, which we consider to be hazardous waste with limited evaluation options.

**The gasification system**; within thermal processes, produces much less flue gas due to its use of partial air and efficient combustion reactions in the oxidizer.

It requires smaller, simpler, and more economical flue gas cleaning systems. It is a thermal system that is much more compliant with air pollution emission directives compared to combustion and is more environmentally friendly.

In this thermal process, dioxins and furans do not form, and minimal NOx is produced.

The result of gasification is char/ash. Char/BioChar has the potential to be transformed into high value-added products such as activated carbon, carbon black, or for soil rehabilitation.

The fundamental reasons for viewing the gasification process as an environmentally friendly thermal process can be summarized as above.

**However**, the biggest handicap of the gasification process is that the **SYNGAS-synthesis gas** produced through gasification is considered a “dirty” gas.

Consequently, when energy is obtained through traditional methods, such as using gas engines with cogeneration, it leads to high-cost and very problematic “syngas” cleaning operations.

## 2- Solution to the Dirty “Syngas” Problem in Gasification

BiMaGAS® **Gasification Power Plant** has addressed the issue of DIRTY SYNTHESIS GAS (SYNGAS) through a rational method in its thermal process. The syngas obtained in the gasification process is directed to the **OXIDIZER** section, where it is combusted along with all solid particles. The resulting hot clean air is then transferred to the **SUPERHEATER** to produce hot oil, hot water, or steam.

A thermal cycle is maintained between the **Superheater** and **the ORC (Organic Rankine Cycle)** Turbine& Generator through circulation pumps. If thermal energy is required only in the form of steam, low-pressure steam can also be produced.

**The ORC turbine and generator system** is an excellent cogeneration unit that produces electricity and heat at capacities ranging from 10% to 100%. The thermal cycle within the turbine system is maintained using a special organic liquid with evaporative properties at low temperatures.

The ORC turbine features easy operational characteristics. Commissioning and maintenance can be performed at very low costs, in shorter timeframes, and with ease.

As a result, BiMaGAS® **Gasification Power Plant** successfully produces simple, easy, safe, and sustainable electricity and thermal energy.

# BiMaGAS® Biomass Power Plant TECHNOLOGY

## 1. FUEL PREPARATION OPERATIONS

The efficiency and sustainable operation of the BiMaGAS® Power Plant depend on the proper preparation of the waste fuel stock.

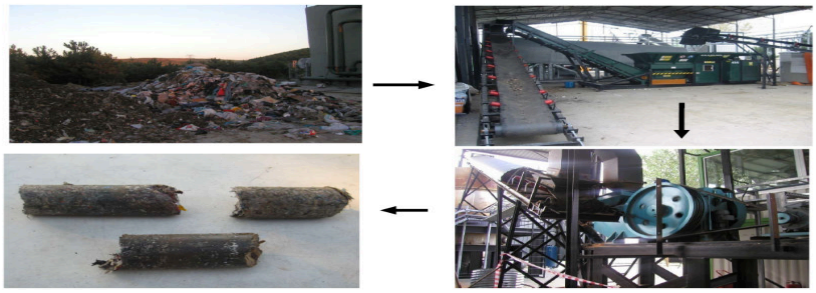

*Figure 3: RDF-Pellet Preparation*

To prepare biomass for the gasification process, municipal solid waste (MSW) is separated through RECYCLING/recovery units that process metals, glass, and other similar waste. The remaining mass is then prepared in RDF/pellet form. Other raw materials may also require drying processes based on their moisture content, using various methods if necessary. Furthermore, the mixed fuels must be categorized based on their calorific values and prepared in a homogeneous structure to produce pellets with a stable calorific value and dryness, which is essential for the efficient operation of the gasification reactor.

Sludge from wastewater treatment plants with a solid content of 22-25% is pelletized after being dried to levels of 85-90% using various methods.

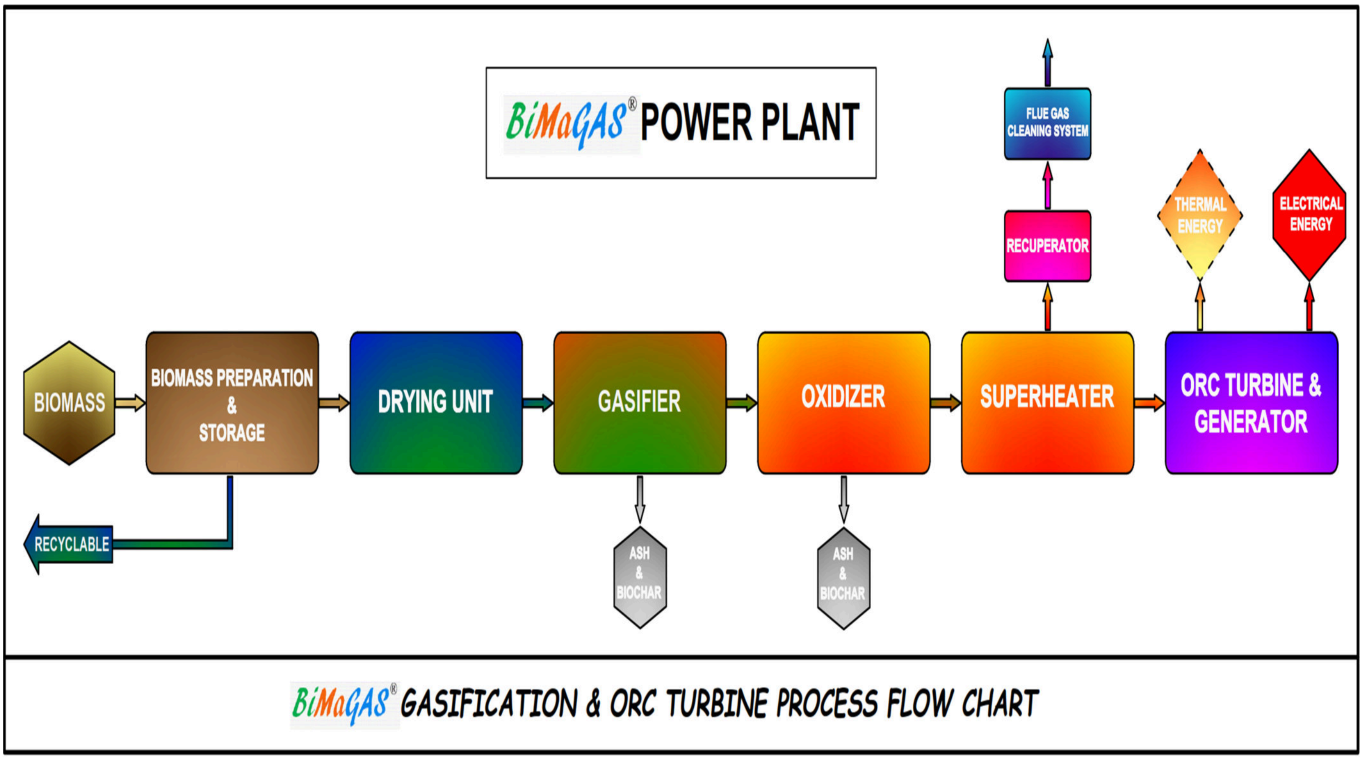


*Figure 4: BiMaGAS ® Gasification Power Plant Process Flow Diagram*

# BiMaGAS® Biomass Power Plant TECHNOLOGY

## 2. GASIFICATION REACTOR/GASIFIER

The fuel, with a stable dryness **(DS > 85%)** and calorific value **(LHV > 15 MJ/kg)**, is fed into the Gasifier/Gasification Reactor operating in the temperature range of **900-1300 °C**. In this reactor, **it is gasified with partial air** to produce **SYNGAS**. **The Thermo-Chemical Reactions** are as follows:

**''Partial Oxidation'':**

1. $C + ½ O_2 \rightarrow CO$ (-111 MJ/kmol)
2. $CO + ½ O_2 \rightarrow CO_2$ (-283 MJ/kmol)
3. $H_2 + ½ O_2 \rightarrow H_2O$ (-242 MJ/kmol)

**''Gasification (Reduction)'':**

1. $C + H_2O \leftrightarrow CO + H_2$ (+131 MJ/kmol) "the Water-Gas Reaction"
2. $C + CO_2 \leftrightarrow 2CO$ (+172 MJ/kmol) "the Boudouard Reaction"
3. $C + 2H_2 \leftrightarrow CH_4$ (-75 MJ/kmol) "the Methanation Reaction"
4. $CO + H_2O \leftrightarrow CO2 + H_2$ (-41 MJ/kmol) "Water-Gas-Shift Reaction"
5. $CH_4 + H_2O \leftrightarrow CO_2{+}3H_2$ (+206 MJ/kmol) "Steam-Methane-Reforming''

The composition of **"syngas"** varies according to the biofuel properties and is as follows:

| Syngas | % Vol / Vol |
|---|---|
| $H_2$ | 7.04 |
| CO | 18.48 |
| $CH_4$ | 1.89 |
| $CO_2$ | 12.00 |
| $O_2$ | 0.18 |
| $N_2$ | 60.41 |
| $H_2$ | 7.04 |

The lower heating value of the "Syngas" indicated above is expected to be in the range of **GCV**: **5-7 MJ/m³.**

## 3. SYNGAS OXIDIZER

The **Syngas** produced in the gasifier possesses characteristics of dirty gas with light and/or heavy particulate and tar content, yet it has good combustion properties.

It is subjected to a combustion process **with air (O2**) at a **minimum excess air ratio** and **maximum temperature of 1300 °C.**

At the base of the oxidizer, **ash and char/biochar** are collected and removed from the system.

**The clean hot air** produced in the syngas oxidizer unit is transferred to a specially designed **Superheater** unit for thermal energy production in the form of hot oil, hot water, or steam.

Due to all cleaning operations being conducted in the **Oxidizer**, no **"SMUTS"** problems are expected in the **Superheater**, and heat transfer is achieved with maximum efficiency.

# BiMaGAS® Biomass Power Plant TECHNOLOGY

## 4. SUPERHEATER / SUPER HEAT EXCHANGER

The clean hot flue gas with high thermal energy is used in a specially designed Superheater to produce hot oil, hot water, or low-pressure steam, depending on process requirements. The steam generated in this unit can be directly utilized in operations.

For electricity generation, the hot oil or hot water operates in an integrated system with a circulation pump and the ORC turbine heat exchanger, producing electrical energy and thermal energy from the ORC turbine.

As explained, the Syngas does not come into direct contact with the ORC turbine, which is one of the most crucial approaches for the successful operation and sustainability of the plant.

On the other hand, the flue gas exiting the Superheater is passed through a **RECUPERATOR** system. This system heats the fresh air needed for the system using the remaining flue gas heat.

Before reaching the cleaning systems, the flue gas is brought to an appropriate emission temperature, and the residual heat is recovered, enhancing system efficiency.

## 5. FLUE GAS CLEANING SYSTEMS

Depending on the type and characteristics of the initially prepared fuel/biofuel, the necessary emission removal systems and units are utilized according to the resulting flue gas emissions.

Emission problems are safely and successfully resolved using units such as **DeSOX**, **DeNOX** systems, **Fabric Filters**, and **ESP** (Electrostatic Precipitators Filter).

As a result, clean flue gas containing parameters significantly below the applicable emission values is discharged into the atmosphere through a compliant stack.

## 6. ORC - Organic Rankine Cycle / TURBINE & GENERATOR

In the ORC turbine process, the **organic fluid** circulating between the ORC heat exchanger and the Superheater transitions to the gas phase in the ORC heat exchanger.

**Electricity Energy** and **Thermal Energy** are produced in the ORC Turbine & Generator System using the organic fluid subjected to a closed cycle under thermodynamic conditions of the ORC (Organic Rankine Cycle).

The integrated gasification power plant **system thermal efficiency is approximately 78%.** Based on 100% dry matter with a calorific value of 15 MJ/kg, the plant expects to produce approximately **1.0 MWe-h of electrical energy** and **3.4 MWth-h of thermal energy with a fuel input of 1375 kg/h**.

If the WWTP bio-sludge is used as fuel (feedstock) with 22% dryness, the heat produced in the ORC Turbine & Generator system is transferred to the thermal drying unit and used in the drying of the sludge. In the integrated system's thermodynamic balances, there will be no additional heat requirement for drying.

In the case of different fuel/biofuel (feedstock) types, the increased dry matter content of the fuel allows the excess thermal energy to be used for greenhouse heating, swimming pool heating, or household heating needs, among others.

## BiMaGAS® Biomass Power Plant TECHNOLOGY


*Figure 5. ORC Turbine & Generator*

## 7. BiMaGAS® Power Plant - CAPACITY TABLE

| Product Name | Dry Biomass (ton/day) | DS % | Electricity Generation (kWe-h) | Heat Generation (kWth-h) | Biochar Production (ton/day) |
|---|---|---|---|---|---|
| BiMaGAS-2000 | 72 | 85 | 2.000 | 6.800 | 7,2 |
| BiMaGAS-1500 | 54 | 85 | 1.500 | 5.100 | 5,4 |
| BiMaGAS-1000 | 36 | 85 | 1.000 | 3.400 | 3,6 |
| BiMaGAS-750 | 27 | 85 | 750 | 2.550 | 2,7 |
| BiMaGAS-600 | 21,6 | 85 | 600 | 2.040 | 2,1 |
| BiMaGAS-500 | 18 | 85 | 500 | 1.700 | 1,8 |
| BiMaGAS-400 | 14,4 | 85 | 400 | 1.360 | 1,4 |
| BiMaGAS-300 | 10,8 | 85 | 300 | 1.020 | 1,1 |