A SUSTAINABLE WAY TO ENERGY

EQTEC GASIFIER TECHNOLOGY

EQTEC

POWER • HEAT • PROCESS

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INTRODUCTION

Of all the thermochemical transformations used to recover energy from waste, Gasification has proven to be, from both energy and exergy perspectives, the most efficient and to have the lowest environmental impact.

Since 1997, EQTEC has been developing its own gasification technologies based on a fluidised bed reactor - EQTEC Gasifier Technology - for the gasification of a wide range of combustible materials (waste), that guarantees a high level of availability and reliability in the plants we design and build, ensuring:

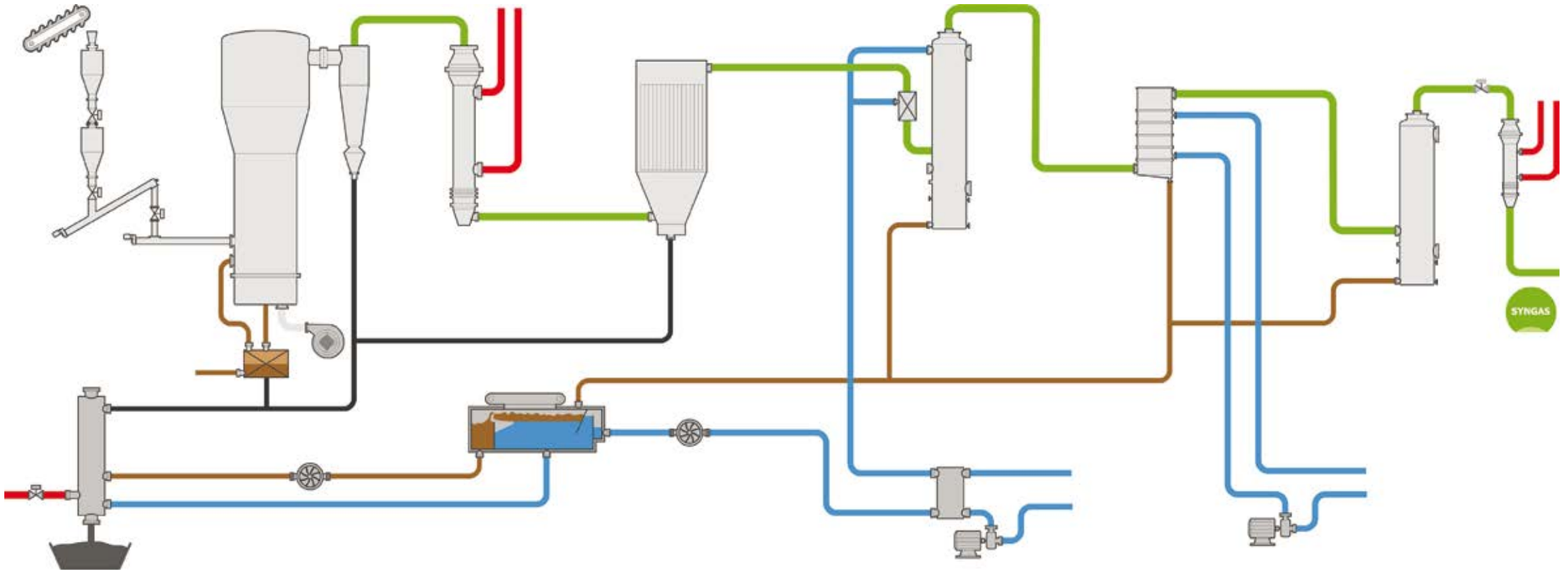
- Maximum energy yield (thermal and electric)
- Respect for the environment in accordance with the existing regulations
- Excellent economic benefits

EQTEC currently has two patents pending that protect this technology.

In addition, in the plants that we design and build, EQTEC uses other technologies that complement the energy recovery process and has agreements with important suppliers in the energy market.

In general terms the gasification plants that the company develops can be described in terms of the area or areas where the main physical-chemical and energy transformations take place, thus:

- Waste reception and storage area
- Gasification area
- Synthesis gas purification area
- Electric power generation area
- Thermal energy recovery area
- Auxiliary services area
- Emissions control area



GASIFICATION

Gasification is defined as the thermochemical transformation of waste –in general material containing carbon– into a gas fuel, known as synthesis gas (syngas).

Gasification is a highly complex process that covers a great many chemical reactions associated with material and heat transfer phenomena. Nevertheless for practical purposes and considering that they occur consecutively and simultaneously in the case of the fluidised bed, they can be grouped into three stages.

1. When the process begins, with the arrival of the waste to the gasifier, there is an initial drying process to remove the water contained in the material (represented in the reaction [1]) and that occurs with practically no chemical reaction.

2. Afterwards, this dry waste is decomposed at temperatures above 300ºC, forming a mixture of solids, liquids (primary tars) and gases. This stage is called pyrolysis or devolatilisation (represented in reactions [2] and [3]). The solid resulting from this thermal degradation is called "char" and the liquids, due to their partial tar and condensable vapour content are commonly described as "tar". The relative yields of gas, tars and "char" will mainly depend on the speed of heating, the final temperature of the process and the configuration of the gasifier.

3. When the temperature of the "char" exceeds 700ºC, as is the case for the temperature range habitually reached with EQTEC Gasifier Technology, the gaseous, liquid and solid products from the stages described above react with each other and the gasifying agent (air) to create a final gaseous mixture. This stage, constituted by heterogenous (solid-gas) and homogenous (gas-gas) reactions, is generically called gasification.

WET WASTE + HEAT → DRY WASTE [1]

DRY WASTE + HEAT → CARBON WASTE (CHAR) + LIQUIDS (TAR) + GASES [2]

LIQUIDS + HEAT → GASES [3]

During the gasification process there are more than 100 chemical reactions, some of which are described in this document.

The heat necessary for the reduction reactions to occur (markedly endothermic and represented in reactions [10] to [18]) is generated when oxidation takes place (exothermic, represented by [4] to [9]). The reactions of hydrogenation, [12] and [14], and reforming, [15] and [17], depending on the conditions (humidity and partial CO2 pressure), take place to a lesser extent.

C	+	½ O2	→	CO			ΔH25 ºC = -26.5 kcal/mol	[4]
C	+	O2	→	CO2			ΔH25 ºC = -94.5 kcal/mol	[5]
CO	+	½ O2	→	CO2			ΔH25 ºC = -67.4 kcal/mol	[6]
H2	+	½ O2	→	H2O			ΔH25 ºC = -57.8 kcal/mol	[7]
CH4	+	2 O2	→	CO2	+	2 H2O	ΔH25 ºC = -191.8 kcal/mol	[8]
C2H4	+	3 O2	→	2 CO2	+	2 H2O	ΔH25 ºC = -317.2 kcal/mol	[9]
C	+	H2O	↔	CO	+	H2	ΔH25 ºC = 31.5 kcal/mol	[10]
C	+	2 H2O	↔	CO2	+	H2	ΔH25 ºC = 21.7 kcal/mol	[11]
C	+	2 H2	↔	CH4			ΔH25 ºC = -18.0 kcal/mol	[12]
C	+	CO2	↔	2 CO			ΔH25 ºC = 41.4 kcal/mol	[13]
CnH2n	+	H2	↔	CnH2n+2				[14]
CnHm	+	n H2O	↔	n CO	+	(n+m/2) H2		[15]
CH4	+	H2O	↔	CO	+	3 H2	ΔH25 ºC = 48.5 kcal/mol	[16]
CH4	+	2 H2O	↔	CO2	+	4 H2	ΔH25 ºC = 39.6 kcal/mol	[17]
CO	+	H2O	↔	CO2	+	H2	ΔH25 ºC = -9.8 kcal/mol	[18]

The final result is a gas basically composed of H2, CO, CO2, (CH4, C2Hn, H2O, N2, a minority of tars and suspended solid particles.

EQTEC has developed its own computer assisted kinetics model capable of simulating the main chemical reactions that occur in a gasifier with EQTEC Gasifier Technology, accurately predicting the chemical composition of the gas generated.

It is important to note that the process conditions in EQTEC gasifiers achieve carbon to gas conversions of approximately 95% and a very low concentration of tars around 5 g/m^3N of gas to the gasifier output.

In this whole process, the pyrolysis or devolatilisation occurs more quickly than gasification, in other words at lower temperatures, and the results will depend on the components generated in this stage, so this is the stage that will control the global process. Therefore the EQTEC Gasifier Technology achieves the rapid deterioration of the solid under these conditions in the fluidised bed, where very high heating speeds are reached.

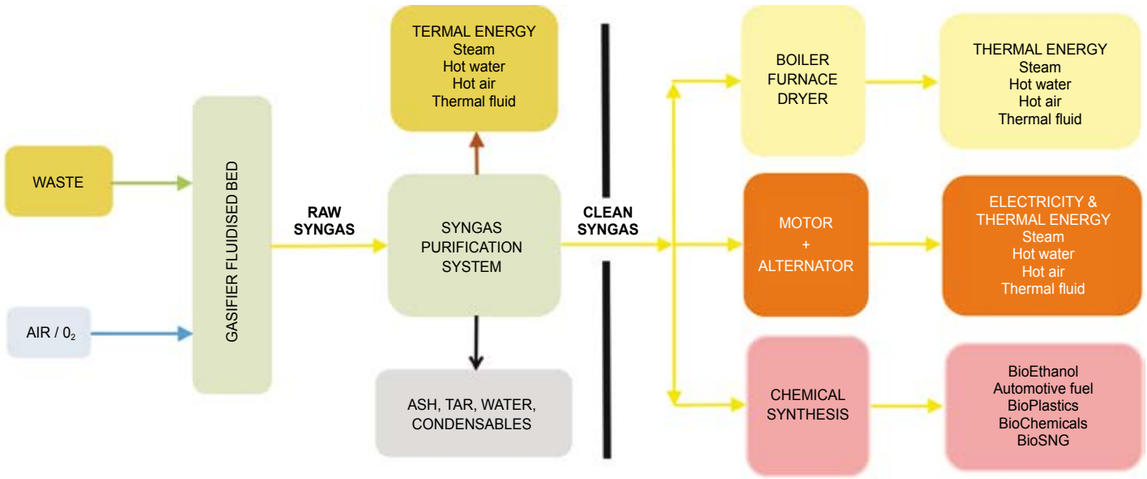
To always guarantee these conditions, the Technical Department of EQTEC analyses and assesses the thermal deterioration of each waste to gasify using analytical methods that offer the necessary information for the optimum design in each case, including:

- Elemental analysis
- Immediate analysis
- Analysis of the ash composition
- Analysis of ash softening and melting temperatures
- Thermogravimetry (TG)
- Differential thermal analysis (DTA)
- Differential scanning calorimetry (DSC)

The studies arising from this allow us to analyse the degradation of the waste as the sum of the degradation of the different primary compounds that make up the fuel.

PROCESS DESCRIPTION

The Flowchart shown in the following figure runs through the different stages of the gasification process using EQTEC Gasifier Technology.



EQTEC GASIFIER TECHNOLOGY

APPLICATIONS OF SYNGAS

Each of the stages is set out below.

WASTE RECEPTION AND STORAGE AREA

The combustible material reaches the plant in the form of pellets or chips; a continuous weighing system guarantees the control of the amount of combustible materials that is received in the installation. The waste is then stored in a building with a proper roof and flooring or directly in storage silos.

In this reception area, the specialised personnel inspect and sample the material for analysis in the plant laboratory which enables an immediate response to the process settings to guarantee optimum gasification conditions for the material.

The waste is transported from the warehouse or silo to the gasification area by mechanical means (bucket elevators, screw feeds, conveyor belts, etc.).

GASIFICATION AREA

Dosage of combustible materials (waste)

The combustible materials are fed into the gasifier via a water-cooled screw feed connected to an electric motor with speed variator to control the amount of waste supplied, depending on its density.

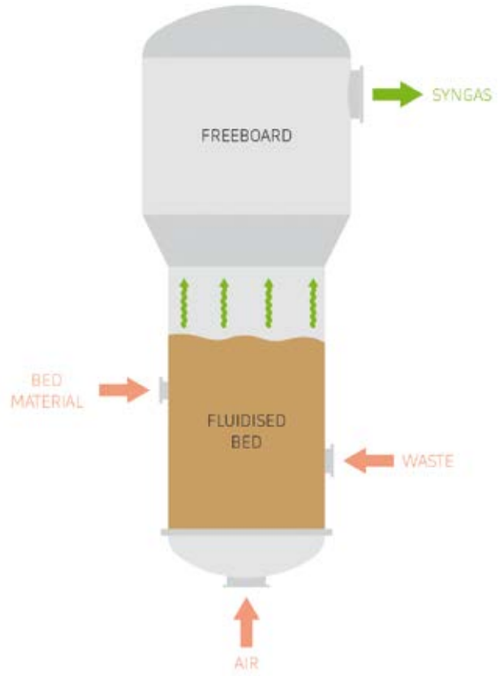
This transporter is fed with a system of hoppers with continuous weighing using load cells where the material is received from the warehouse area.

Gasifier

The EQTEC Gasifier Technology reactor consists of a steel container, usually cylindrical, coated on the inside with a layer of refractory insulation material. It is a bubbling fluidised bed reactor; this type of reactor is widely used due to its versatility in terms of the diversity of solid fuel to gasify, because it achieves a better mixture between inert and combustible material due to its high heat transfer index and because it reaches high heating speeds, among other advantages.

This technology is widely known and well established due to its easy operation and thermal yield, which EQTEC has improved with over 16 years of accumulated experience in the design, construction and operation of this type of reactor.

Diagram of operation and image of a fluidised bed Gasifier using EQTEC Gasifier Technology



Inside, a bed of solid particles is maintained fluidised by an air current that enters at the back of the reactor. The pressure shall be slightly higher than atmospheric pressure and the temperature higher than 800ºC.

The fluidisation air is supplied by a compressor and is uniformly distributed at the bottom of the reactor by an air distribution grille with nozzle type diffusers (tuyère).

EQTEC Gasifier Technology also enables the use of mineral catalysts to accelerate the decomposition reactions in combustible materials with a low reactivity (waste) thus guaranteeing its high performance.

These conditions of operation and design favour the optimum decomposition of the combustible materials (waste) to give rise to the current of gas fuel or synthesis gas at a high temperature that leaves the reactor through the top.

The hot synthesis gas that leaves the reactor passes through a conventional cyclone followed by another high efficiency cyclone, where the majority of the particles suspended in the gas are removed. The decelerating hoppers joined to the back of each cyclone help capture the particles.

Solid retention and re-circulation system

For this system, which is of vital significance in making use of the solid fuel carried by the gas current, EQTEC employs conventional particle separation systems (cyclonic spacers). These particles are retained in the cyclone due to the centrifugal and gravitational forces that lead this flow of solids to the re-circulation area.

The flow of particles is driven by a mechanical system (Return Leg/L-Valve) to the reaction area inside the fluidised bed of the gasifier to completely exhaust its available chemical energy and achieve a high yield in the conversion of the combustible solid.

Optionally and in cases where “fine” (low ash content) combustibles are gasified where very high levels of conversion are reached inside of gasifier, because of its design based on fluid dynamics, the system enables the direct extraction of this current prior to cooling to make use of the thermal power available in this waste for useful means inside the installation, thus increasing the global energy efficiency of the plant.

Cyclonic separator

SYNTHESIS GAS PURIFICATION SYSTEM

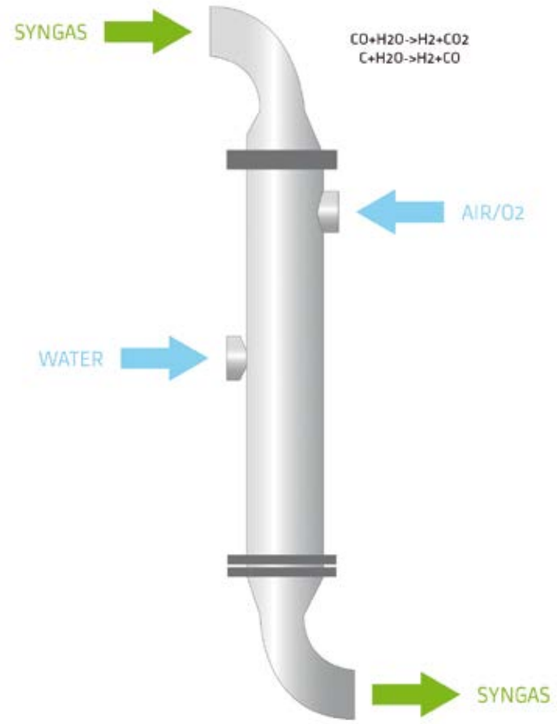
Thermal cracking and reforming reactor

Once the gas has passed through the solid separation system the resulting current is driven to a new thermochemical treatment that reduces the fraction of tars present to the level of milligrams per cubic metre of gas.

The EQTEC thermal cracking and reforming reactor creates the conditions necessary for the decomposition of hydrocarbons (tars) that to a large extent, due to effect of the reactions that take place, become part of the gas current in the form of lighter combustible gaseous compounds that provide heat energy (formation of H2 and CO).

As a result of these operations, the gas leaves the reactor chamber at a temperature of around 600ºC and in a second stage part of its thermal energy is transferred to a heat recovery circuit that supplies other sections of the plant. At the output of this unit the temperature of the gas current is around 340ºC.

Operational diagram of a thermal cracking reactor



Dry cleaning system

The purpose of the dry cleaning is to eliminate the solid particles from the combustible gas current, and with the most advanced technology for hot filtration through membranes (ceramic/sintered metal) EQTEC can eliminate particles of up to 5 microns.

The high gas filtration temperature prevents the condensation of compounds (steam) on the filtering surface thus increasing the system availability and extending the useful life of the membrane, so intervention during the period of scheduled maintenance is sufficient to guarantee proper system operation.

Particulate matter filter

Wet cleaning system

This section guarantees a combustible gas practically free of impurities for subsequent use in power cycles (gas turbine/motor). The wet cleaning system is purification, using liquid cleaning agents (water) in a system specially designed to cause the microcontaminants carried in the gas to adhere to the cleaning solution. This type of cleaning also cools the gas to approximately ambient temperature, thus preventing the formation of contaminants (dioxins and furans) that may appear as a result of the composition of some gasified wastes.

The traces of acid gases or with a certain basicity (HCl, H2SO4, HP3, etc.) that the synthesis gas may have due to impurities of the waste, and practically all the microparticles that have not been retained, are captured by the cleaning water that is sent to the water treatment area.

EQTEC designs and builds the cleaning units installed in its plants as an essential part of the supply to provide environmental guarantees that comply with the strictest legislation on the matter.

Dynamic precipitators

Once the gas leaves the wet cleaning system it is a current saturated with water. Removing as much of this water as possible is very important for the final use of the gas.

EQTEC has studied in detail the conditions in which the precipitation of some compounds of the gas occurs on wet surfaces and to this end has obtained the parameters with which to design and construct the condensation dynamic precipitators that function in parallel in a "Bach" system and whose function is to eliminate the water content (moisture) from the gas current jointly with other compounds carried from the cleaning that may be present in this current. These units are equipped with cleaning and drainage systems and the heat-carrying fluid is water from the cooling towers.

Preparation of the gas for its final use

Once the gas is clean and dry, this current is homogenised and reheated (using part of the thermal energy available that was extracted from the system itself) and taken to the units that are going to consume this gas.

The objective of reheating the gas is to prevent condensation either during its transfer to the machinery room or when it mixes with the intake of cool air for combustion.

Syngas cleaning system

AUXILIARY SERVICES AREA

Another of the areas of the plant that is of vital significance is devoted to the auxiliary services that make the production activity of the installation possible.

EQTEC designs and builds these installations for the proper functioning of the EQTEC Gasifier Technology. Highlights of these installations include:

- Drinking water network
- Nitrogen network
- Network of compressed air for instrumentation
- Process water treatment system
- Heating and ventilation network
- Auxiliary fuel network
- Communications
- Water system for cooling
- Fire prevention system and network
- Monitoring and control system

The monitoring and control system of the installations is of special importance; it is the true "neurological centre" of the plant that enables it to function unattended, without needing the continued presence of the operating staff. This system enables us to instantly know the operational status of the plant, the operation parameters, maintenance needs, energy production and fuel consumption, in short, all of the important data of the installation.

EMISSIONS CONTROL AREA

EQTEC Gasifier Technology is differentiated by its low emission of pollutants. In addition, the installations incorporate an emissions control area that monitors the level of pollution emitted into the atmosphere at all times. EQTEC plants have an emissions focus, which has a set of analysers and recorders with the purpose of quantitively assessing the pollution present in the flow of gases generated by the motor generators and heat recovery.

In the installations the emissions into the atmosphere are analysed both to verify compliance with the current regulations in the area and to determine, among other parameters, the alterations that may occur in the process.

EQTEC generates a protocol for the control and surveillance of the atmospheric pollution that must strictly be observed in the activity of the installation, which reflects the sampling and analysis of the following compounds and principal contaminants in the emissions focus (Motor/Heat Recovery):

- Solid particles (PM)
- Analysis of gases (O2, CO2 and CO)
- Nitrous oxides (NOx)
- Sulphur oxides (SOx)

Thus the strictest compliance with the environmental legislation is guaranteed.

Image of the monitoring and control system

APPLICATIONS OF THE SYNTHESIS GAS

ELECTRIC AND THERMAL POWER GENERATION (CHP)

The main use of the synthesis gas generated in the Gasification area is as fuel in alternative Otto cycle internal combustion engines, which do not need other auxiliary fuels for operation. Alternative engines are coupled to synchronous alternators for the generation of electricity.

The alternators, by means of the corresponding protection and control elements, are connected to a transformer, and subsequently to the electrical grid.

This area is in a building adjacent to the Gasification area to which the synthesis gas and other auxiliary services (inerting nitrogen/water, etc.) are brought.

The alternative engines need cooling in the liners, in the oil sump and in the gas-air mixture cooler. Two closed and independent circuits for cooling with water perform this function. One of the circuits cools the liners, the lubrication oil and the first stage of the gas-air mixture cooler of each engine. The other circuit cools the second stage of the gas-air mixture cooler of each engine.

In the closed circuit for cooling the linings, the oil sumps and the first stages of the gas-air mixture coolers, the water is propelled by centrifugal pumps. Derivations to each of the engines leave from a general manifold. The water enters the engines at a temperature of 70ºC. After passing through the engines and reaching a temperature of 85ºC, a manifold takes the water to the pumps that propel it through a heat exchanger, where it will transfer the heat acquired in the engines and restore the initial temperature of 70ºC. From the heat exchanger the water returns to the general manifold.

In the closed cooling circuit for the second stage of the gas-air mixture cooler of the engines, the water is propelled by a centrifugal pump. Derivations to each of the engines leave from a general manifold. The water enters the engines at a temperature of 50ºC. After passing through the engines and reaching a temperature of approximately 55ºC, a manifold takes the water to the pumps that propel it through a heat exchanger, where it will transfer the heat acquired in the engines and restore its initial temperature of 50ºC. From the heat exchanger the water returns to the general manifold.

6 MWe synthesis gas engine generator room

Thermal energy recovery and elimination of waste

The electric power generation plants designed by EQTEC have a heat exchange area where this application is centralised and from which the heat-carrying fluid flows to different uses inside the installation or to third parties (heat export, hot water or steam) if it is a cogeneration plant (CHP).

The heat is generated in the gasification area the synthesis gas purification system and in the alternative engines of the electric power generation plant.

In the gasification area there is a reactor with advanced technology, with a very high ratio of thermal recovery for processing a wide range of waste (solid, liquid and gas). In an initial stage it reduces the polluting components, converting them into combustible gases that will be degraded through combustion in a second phase.

This system enables solid and liquid waste to be treated, through pyrolysis, gasification and carbonisation, releasing its chemical energy content for later combustion in a gas chamber that is much more efficient. The principle, in all cases, the existing calorific value of the residual material from the gasification process can be used as a primary source of energy for the second phase (combustion in gas stage) which leads to an enormous energy saving to reduce the input of auxiliary heat.

Thus, the installation of a gas torch is avoided, guaranteeing the conversion of all the solid waste of the gasification (generally with a certain organic content) into a solid by-product (ash) with commercial value (as fertilisers, compost, mixture for organic cement, etc.).

This reactor has a high yield, as it permits tiered operation of the waste treatment: drying, pyrolysis, carbonisation, gasification, combustion and oxidation, at different temperatures at each stage from 250°C to 1300°C with different times of residence.

This system performs the oxidation of the waste and purification of the gases and integrates the metals in slag and ash, complying with the environmental regulations for the emission of pollutants.

As result of this application, which is part of the EQTEC Gasifier Technology developed, the waste management is minimised, reduced to the ash that contains the combustible materials that enter the plant. With EQTEC Gasifier Technology we can create zero dumping installations, whose only waste product is the ash from the gasification process, which in many cases can be treated to obtain fertilisers for which there is great demand in the agricultural market.

The thermal energy generated in the form of combustion gases, both in the reactor described above and in the alternative engines, is used (heat recovery) in heat exchangers for the production of thermal energy whether in the form of steam, heat-transfer oil, ACS circuits or in organic sequences (ORC), etc., ensuring the full dedication of the energy from the waste that enters the gasification plant to a final use.

All of the necessary equipment (heat exchangers, thermal fluid boilers, pumps, etc.) is concentrated in this area to achieve the objective of not wasting a single thermal kW that may be used to improve the thermal performance of the plant.

Heat recovery units for the production of hot water

THERMAL ENERGY GENERATION

A second application of the synthesis gas generated in the gasification area is the production of thermal energy by direct combustion of the gas in heat production units, such as steam boilers, cement furnaces, dryers, etc. This thermal energy can be used in various sectors of activity such as the chemical, cement and food industries, etc., in the tertiary sector in offices, hotels and residential buildings (district heating & cooling) or in the agricultural sector (greenhouses).

CHEMICAL SYNTHESIS

A third application of synthesis gas is the production of biofuels or biomaterials by means of chemical synthesis. Synthesis gas consists of a number of chemical compounds such as H2, CO, CO2, (CH4, C2Hn, H2O, N2. This gas is subjected to chemical transformation processes, thus making it possible to generate BioEthanol, Biochemicals (ethylene glycol, DME, methanol), BioSNG, etc. These products are used to produce fuel for automotion and transport, chemical products and plastics, fuel for injection into pipelines etc.

ADVANTAGES OF THE TECHNOLOGY

The notable advantages of the EQTEC Gasifier Technology plants are:

- Higher electric performance than alternative technologies (from 26% to 34%)
- Global energy efficiency (between 75% and 80%)
- Economic feasibility of the electricity generation plants from 1 MWe to 25 MWe
- Modular generation plants
- Environmentally friendly technology Low emissions of pollutants
- Multi-fuel gasification plants

FEEDSTOCK

The gasification plants are designed according to the waste that will be used as the raw material of the plant. The main waste types are:

- Waste from the furniture industry
- Municipal solid waste
- Poultry manure
- Treatment plant sludge
- Plastic waste
- Waste tyres
- Bio-coal
- Animal meal
- Wood chips, wood pellets
- Forestry waste
- Almond shells
- Coconut shells
- Olive stones and pulp
- Grape marc
- Straw pellets
- Sugar cane bagasse
- Coal
- Petroleum coke

PROJECTS

6 MW GENERATION PLANT WITH INTEGRATED GASIFICATION

6 MWe cogeneration plant with integrated gasification installed in Campo de Criptana (Ciudad Real, Spain).

- Raw material: Merc and other agribusiness waste
- Status: In operation since 2011

1 MW GENERATION PLANT WITH INTEGRATED GASIFICATION

1 MWe generation plant with integrated gasification installed in the municipality of Castiglione d'Orcia (Tuscany, Italy).

GASIFICATION PLANT R+D

Gasification plant installed in Badajoz (Spain).

- Raw material: Olive merc
- Status: In operation since 2014

GASIFICATION PLANT

Gasification plant installed in Epinal (Lorraine, France) for thermal use.

- Raw material: Miscanthus pellets, forestry waste
- Status: In the design and construction stage

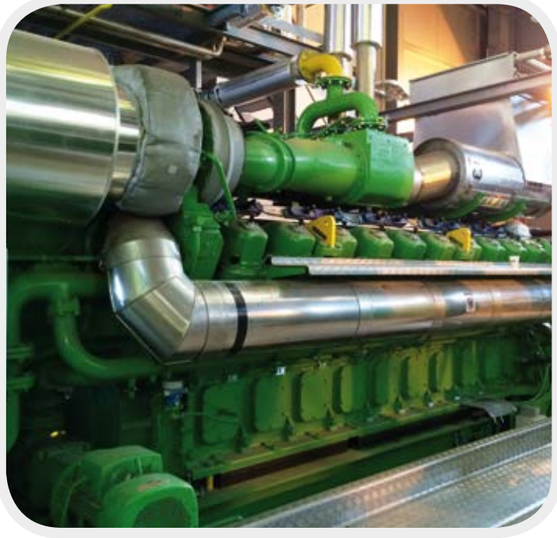
5 MW GENERATION PLANT WITH INTEGRATED GASIFICATION

5 MWe generation plant with integrated gasification in the municipality of Stroevo (Bulgaria).

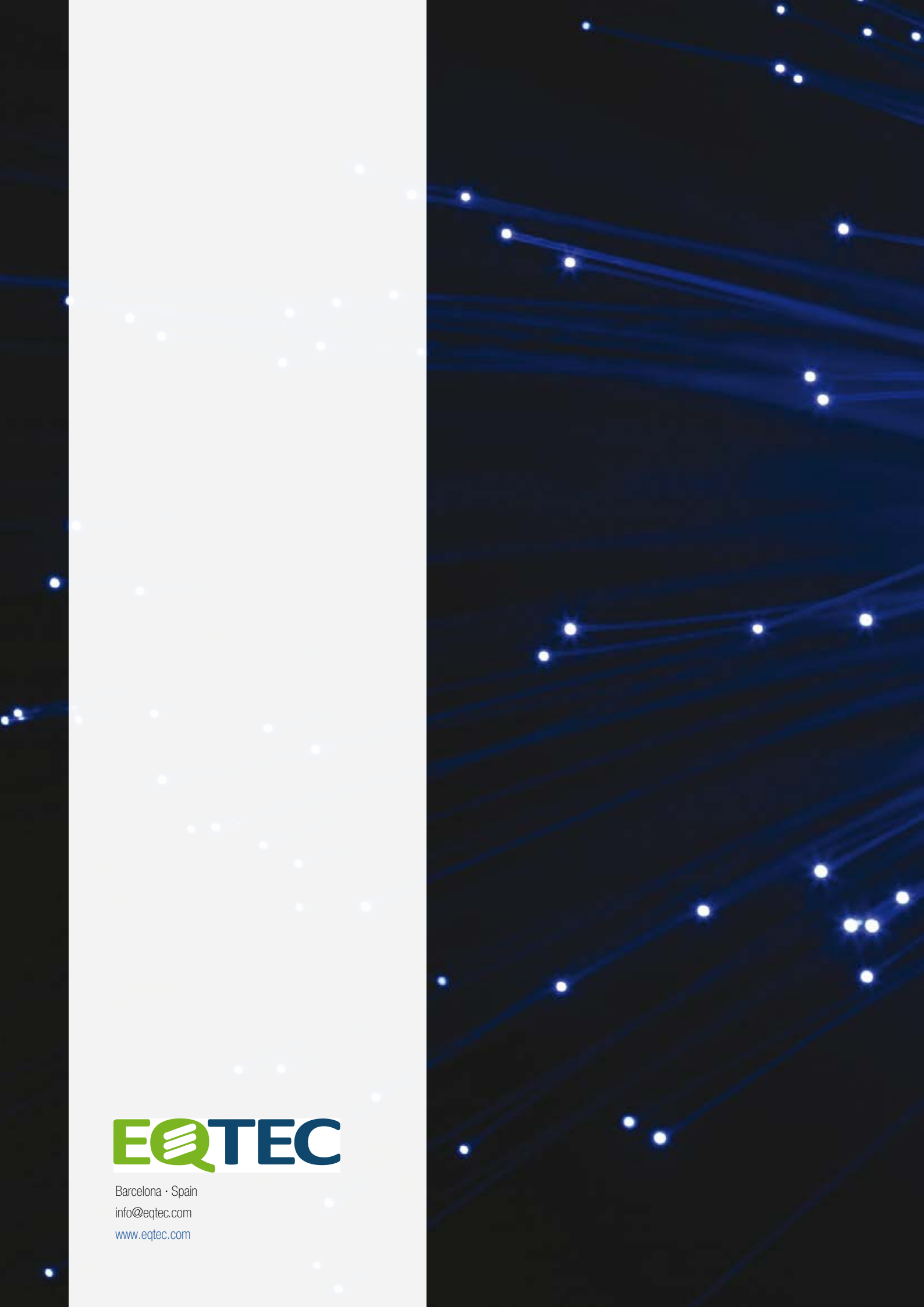










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