Biogreen®

Multipurpose pyrolysis unit for biomass and waste conversion

www.biogreen-energy.com

ETIA
ECOTECHNOLOGIES

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1. GENERAL INFORMATION

1.1. Intended use of Biogreen©

Biogreen© is a continuous process for converting potential energy of material into energy that is easy to use (liquid form, solid form, gas form).

System allows to treat various bulk materials (biomass, biosolids, waste) into high value products (syngas, biochar, oil compounds, solid fuels and other).

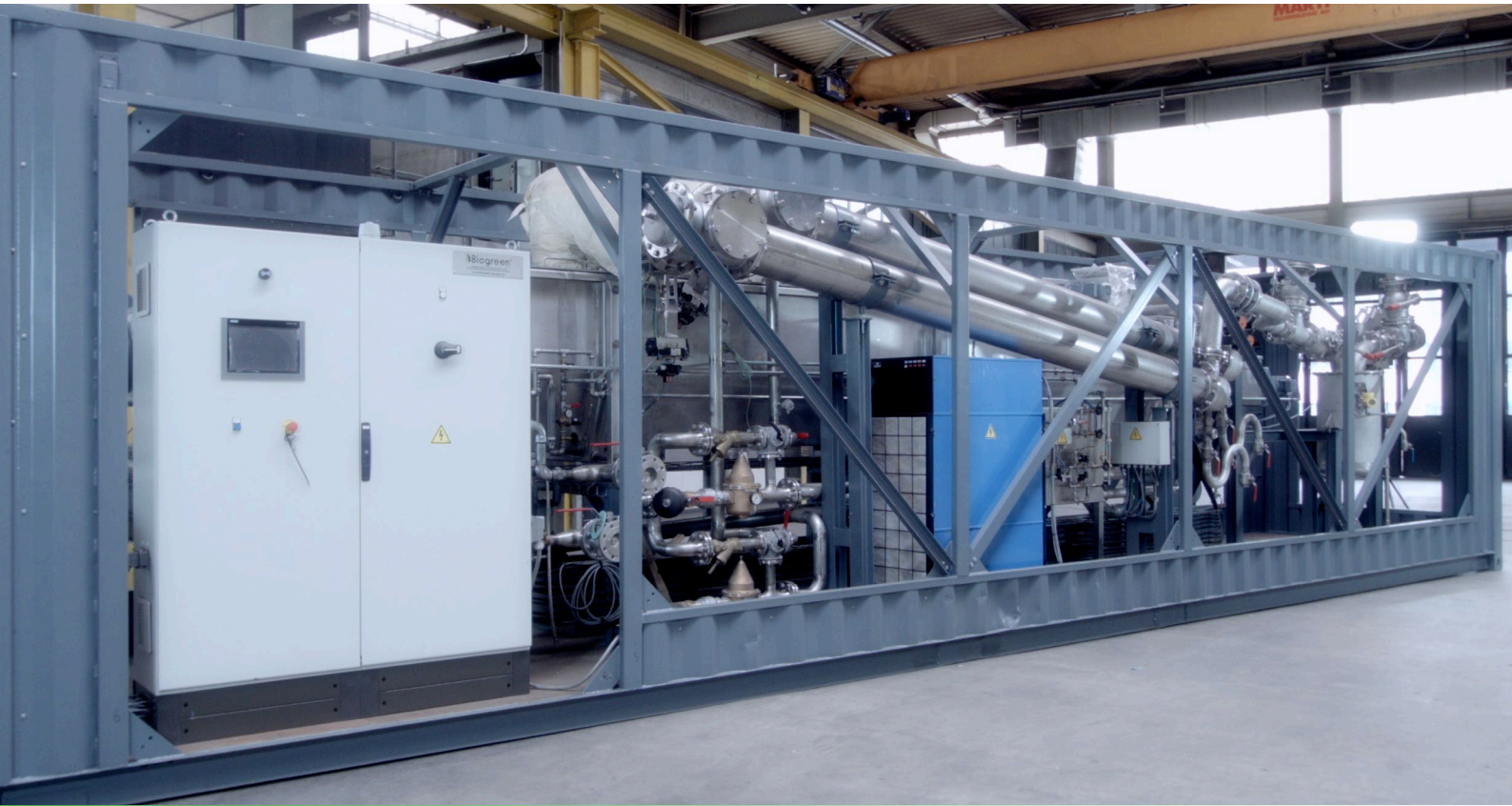
Reliability and performance of system has been demonstrated for over a decade of operation, which makes Biogreen® a leading pyrolysis system in Europe. Equipment simplicity ensures high reliability combined with low maintenance and operating costs, while controlled conditions of process make Biogreen© a perfect solution for turning waste into products.

Since many years, Biogreen© supports the industry in sustainable management of generated waste and biomass, including following areas:

- solid fuels production from biomass (torrefaction process)
- biochar (soil enhancer) production
- conversion of dry sludges into heat and energy
- oil from biomass extraction for variety of applications
- municipal waste, industrial waste (RDF / SRF), plastics conversion into energy

1.2. Standard technical data

Manufacturer	ETIA S.A.S.
Conformity standard	CE
Type of pyrolysis unit	Electrical heated auger reactor
Treatment temperatures available	200 - 800 ºC
Operating mode	Torrefaction, pyrolysis (air absence atmosphere)
Conversion efficiency	80 - 95% (output energy / input energy)
Operating pressure	Below atmospheric
Electrical connection	400 V tri - 50 Hz
Available fabrication options	Containerised unit / stationary plant
Operating environment temperature	0 - 45 ºC
Operating humidity	max. 85% HR
ATEX area of operation	not supported
Operation in dust polluted area	not supported
Noise emissions	76 dB(A)
External surfaces temperature	< 60 ºC
Startup time	3 - 5 h. (cold startup) / 15 min. (hot startup)



2. OPERATING DATA

2.1. Feedstock specification

To standardise its performance, Biogreen© system is designed to process feedstock according to the specification below:

Average particle size	max. 20 mm
Relative moisture content	max. 10%
Apparent bulk density	150 - 700 kg/m^3 min. 300 kg/m^3 recommended for polymeric waste[1]
Material quality	Free of metals
	Free of glass and stones
	Minimum inert content

[1] Polymeric waste: plastics, RDF / SRF, calorific fractions of municipal and industrial waste. In case of lower density we recommend pelletising the material for obtaining highest quality of process.

2.2. Process information

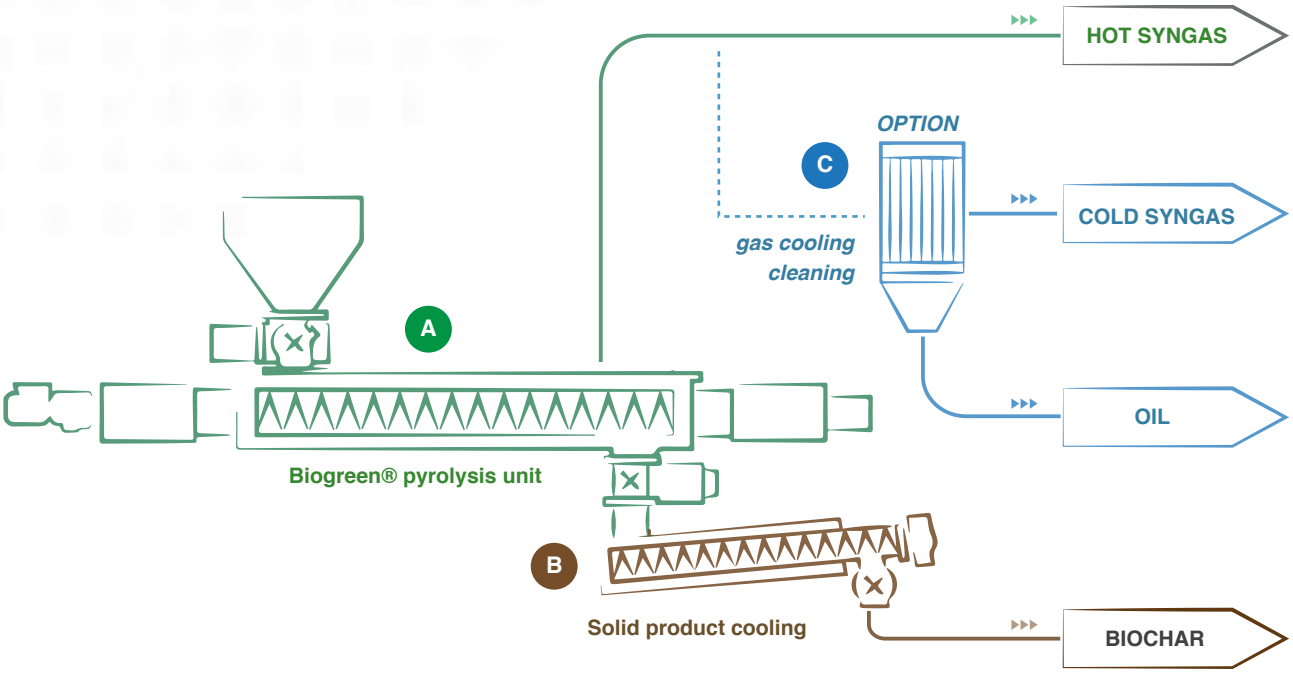
Feedstock	biomass / biosolids[1]	polymeric wastes[2]	rubber[3]
Treatment temperatures applicable	250 - 700 °C	650 - 800 °C	650 - 800 °C
Residence time of feedstock	5 - 15 min.	15 - 25 min.	15 - 25 min.
Synthesis gas (syngas) (% mass)	15 - 80%	60 - 95%	30 - 60%
Oil after cooling (% mass)	5 - 40 %	5 - 30%	20 - 40%
Char produced (% mass)	15 - 90%[4]	2 - 30%	35 - 45%

1. *wood chips, sawdust, plant shells, dry sludges (…)*
2. *plastics, RDF / SRF, calorific fractions of municipal and industrial waste*
3. *rubber from waste tires*
4. *variation depending on operating conditions (torrefaction / pyrolysis / high temperature pyrolysis)*

2.3. Fuel and energy consumption

Electrical consumption of Biogreen® ("parasitic load") ranges between 60 to 450 kW per tonne of input material and depends on type of feedstock processed, applied operating conditions (torrefaction, medium temperature pyrolysis, high temperature pyrolysis) as well as management route of the syngas and char.

Parasitic load of system divides between energy necessary to heat the pyrolysis process (A), power required to cool down the obtained quantity of solid product (B) and eventual cooling of the syngas (C - option).



Other fluid and media consumption		Consumption mode
Industrial water	0,1 - 0.15 l. per 1 kg of solid product	Continuous, biochar stabilisation
Nitrogen	2 - 10 Nm3	Non-continuous (start / stop and security phases)
Other effluents	According to level of feedstock pollutants and demand	Optional - continuous (gas cleaning system)

2.4. Synthesis gas (syngas)

Pyrolysis process results in production of calorific syngas at heating value up to 36 MJ/Nm^3 (pyrolysis of plastics).

Syngas leaving the Biogreen reactor is a hot mixture of condensable and non-condensable phases. In this state, it can be subject of eventual treatment (particle matter removal, adsorbtion of pollutants) and considered as an energy source as a fuel for **high temperature gas burners** that ETIA can provide with its Gasflex dual fuel syngas burners.

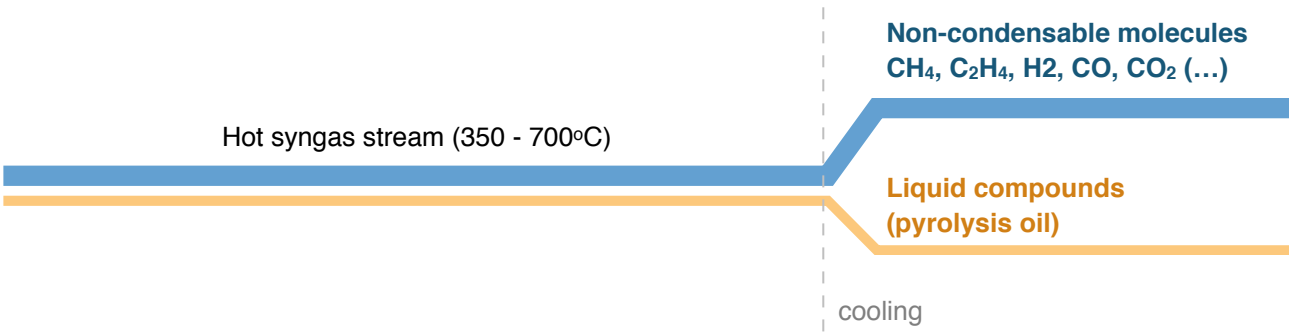
Directions of **hot syngas** utilisation:

- heat production for drying or industrial purposes
- industrial steam or thermal oil production
- replacement of conventional fuel in the existing boilers
- electricity generation via ORC
- electricity generation via steam turbine

Applications focused on **ambient temperature syngas** utilisation are linked with energy expenditure for cooling down the syngas and extraction of liquid phase - pyrolysis oil. Syngas at ambient temperature is easier to transport and offers wide scope of perspectives for it's treatment, separation of molecules and utilisation.

Directions of **ambient temperature syngas** utilisation:

- electricity generation via internal combustion engine
- electricity generation via gas turbine
- methane to grid production
- hydrogen production
- fuel cells utilisation
- other special applications



Example syngas compositions

% vol	H_2	CH_4	C_2 - C_4	CO	CO_2	N_2	density (kg/Nm3)	**LHV (MJ/Nm3)**	**kWth / tonne inlet**
RDF	16%	25%	24%	18%	15%	2%	1,05	**27,30**	4 694
biomass	15%	26%	3%	35%	17%	4%	1,10	**17,10**	2 591
plastics	25%	38%	18%	9%	5%	5%	0,80	**28,00**	7 778
tires	19%	40%	28%	3,5%	6,5%	3%	0,90	**36,00**	3 333

** Non-condensable fractions of syngas at ambient temperature*

2.5. Liquid products

Pyrolysis oil is a liquid substance obtained in result of pyrolysis process and subsequent cooling. It is a complex blends of molecules usually consisting more than 300 compounds resulting from the depolymerisation of products treated in pyrolysis.

Pyrolysis oil remain interesting source of **bio-chemicals and renewable compounds** that meet significant market interest.

Although often high LHV (12 - 22 MJ/kg), oil from waste pyrolysis process require further treatment to ensure it's stability and compatibility with existing **petroleum based fuels.**

Selected types of feedstock and tailored made-processes of clean biomass pyrolysis can allow to obtain high quality and value oils that can be used as **food aromas (liquid smoke)**, plant protectors or growth enhancers (**wood vinegar**).

Directions of **pyrolysis oil** utilisation:

- source of bio-molecules
- fuel for further refining
- food aromas (liquid smoke)
- pesticides and plant enhancers (wood vinegar)

2.6. Solid products

Quantities and parameters of solid residue obtained in pyrolysis process depend on the treatment conditions and quality of raw material processed.

Depending on it's character, solid residue of pyrolysis often represents significant market value and remains one of core objectives of the process. Several types of products obtained in the process are highlighted below.

biochar from sawdust (550°C) 28 MJ/kg

char from RDF, SRF pellet (800°C) 10 MJ/kg

charcoal pelletised after the process 26 MJ/kg

char from pelletised biomass 28 MJ/kg

Biochar

Raw material: Non-polluted biomass
Treatment: Pyrolysis, 450 - 600 °C

Biochar is a solid product obtained in pyrolysis of biomass. As a product, it can be used for a wide range of applications that include soil improvement, remediation and pollution control.

As a product, biochar differs from charcoal, which is produced at lower temperatures and considered as solid fuel, containing high quantity of volatile matter. In contrary to biochar, charcoal is considered phytotoxic and it's application covers solid fuels attractive for combustion.

Biochar is primarily used in agriculture to enhance soil fertility, improve plant growth, and provide crop nutrition. As a result, it, improves the overall productivity. It has also gained considerable popularity in livestock farming as an animal feed. The livestock sector is extremely crucial for biochar, especially in regions such as the North America and Europe where meat is important for human consumption.

Selected directions of **biochar** utilisation:

- soil additive: water retention product (Hydrochar®)
- soil conditioner: nutrients carrier
- soil remediation assistant
- precursor for activated carbon
- filtration / decontamination material
- animal feed additive

EMERGING MARKET

"The global demand for biochar exceeded 280 kilo tons in 2015 and is expected to grow at a CAGR of 12.15% from 2016 to 2025"

Grand View Research, Inc.

Charcoal, bio-coal and solid fuel

Raw material: Biomass, biosolids, plant shells, dry sewage sludge
Treatment: Pyrolysis, 250 - 400 ^{o}C

Torrefaction of biomass and biosolids leads to obtaining a dry product with enhanced fuel properties, which leads to production of very good energy carrier that features LHV of above 21 MJ/kg and up to 28 MJ/kg.

With further densification (pelletising, briquetting) high energy density of 18-20 GJ/m3 is feasible to achieve, which comparing to values of raw biomass allows to propose 40-50% of reduction in transportation costs.

Torrefaction allows to improve material's storage properties due to achieving hydrophobic properties and elimination of any biological activity. This eliminates the risk of repelling water and biological decompositions like rotting.

Process leads also to improved grindability of biomass, which guarantees better combustion properties.

Directions of **torrefied fuel** utilisation:

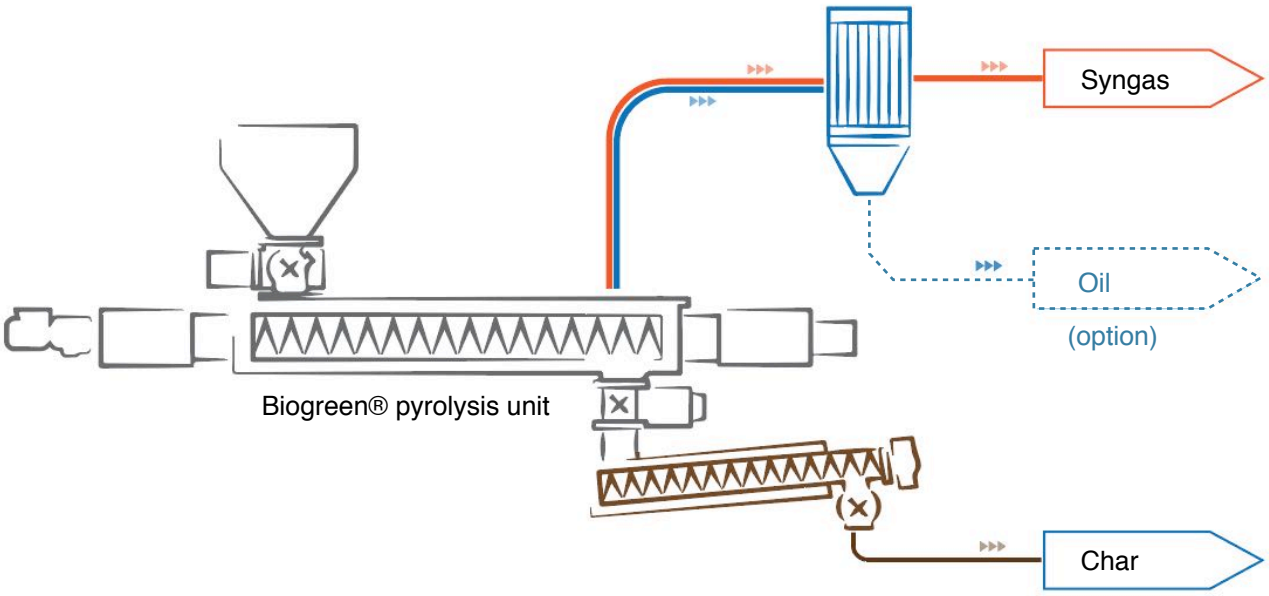
- solid fuels for local and decentrilised applications
- co-firing in existing coal-fired power stations
- alternatives and replacement for conventional fuels
- coal replacement in steel production industry
- wood powder fuels

3. GENERAL DESCRIPTION OF THE INSTALLATION

3.1. Overview

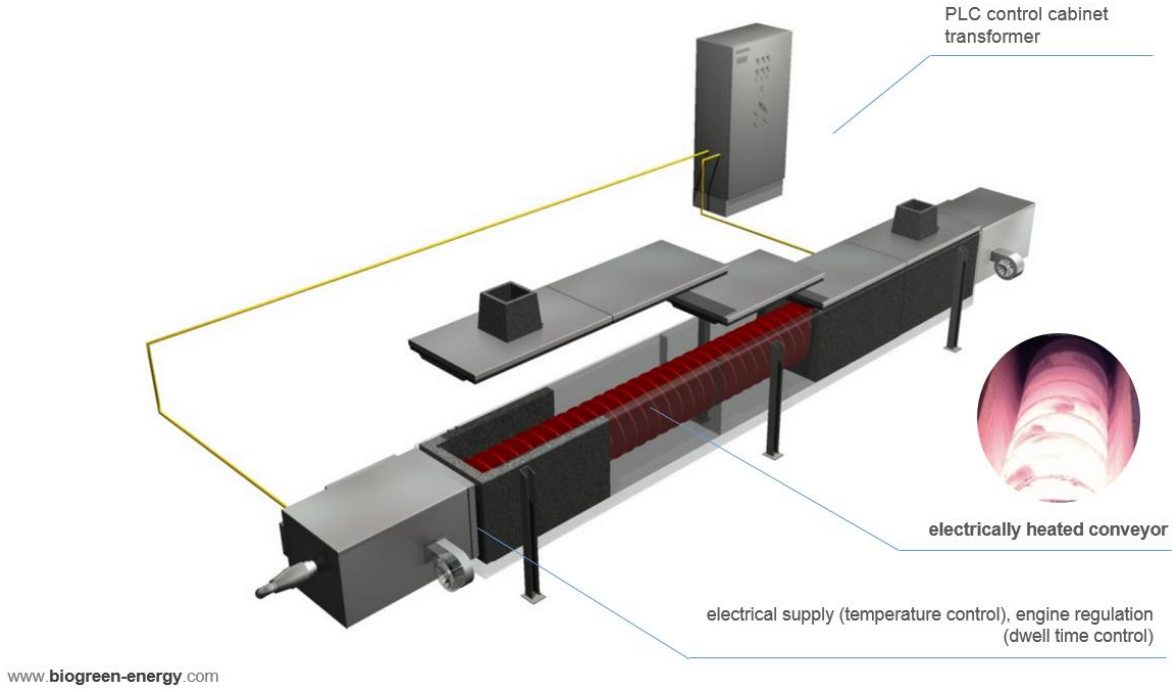
How Biogreen works

1. Raw material can be dried, shredded and densified before the process in order to reach the demanded moisture and apparent density. ETIA can also supply continuous dryer equipment prior to Biogreen® process unit in order to prepare the feedstock for the Biogreen® process.
2. Material is introduced to a Biogreen® hopper with regular and controlled flow. Particle size and moisture will affect the yield of solid, oil and gas.
3. A high temperature rotary valve or dosing screw introduces the material into the pyrolysis chamber. This chamber is based on Spirajoule® technology, an exclusive and patented electrical heating screw conveyor designed by ETIA. Process allows perfect monitoring and control of product dwell time and temperature during the treatment. Temperature of conversion can be adjusted precisely up to 800°C, depending on specifications required. Dwell time of the product in the pyrolysis chamber can be adjusted from 5 to 30 min. Choice of operating conditions defines the ratio of syngas, oil and solid product generated with the process.
4. Syngas generated in the process exits the top of the Spirajoule® pyrolyzing chamber and arrives to the system of particle matter removal (cyclone or ceramic filter). After separating the particle matter, gas can be either is directed to combustion chamber or dedicated cooling system that separates the non-condensable (NCG) and condensable fraction of syngas. Cooling system (option) consists primary and secondary equipment for reducing the syngas temperature and extracting its condensable part. Tars, oil and water are the liquid phase are being condensed during the process of gas cooling down. The yield of liquid phases obtained in the treatment depends on waste composition and Biogreen® operating conditions.
5. Solid phase (biochar) coming out from Spirajoule® pyrolyzing unit is quickly cooled down in a flash cooler (UPZ®) based on a double jacketed auger cooling screw mounted with water spraying device. Solids are cooled down to a temperature not exceeding 60°C. The ratio of biomass converted into solid products depends on feedstock composition and operating conditions.
6. The non-condensable gas (NCG) coming out from the cooling system features high energy value. It can be managed in multiple ways to create power and heat.



Spirajoule®

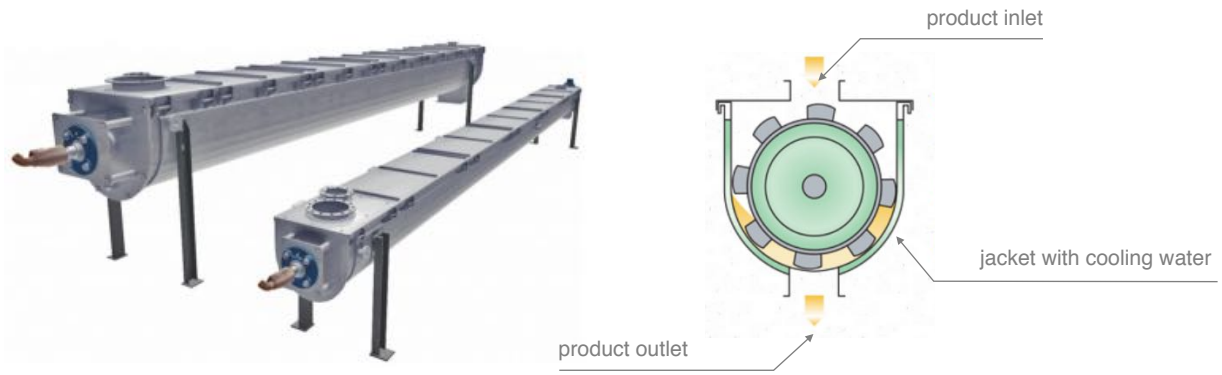
Biogreen technology is based on electrically heated screw conveyor (Spirajoule®) designed for advanced thermal treatment in pyrolysis conditions. Screw conveyor heats the product inside the reactor as a result of the Joule effect. The product temperature is precisely controlled basing on the temperature settings. The dwell time of material inside Biogreen® reactor is regulated by screw rotation speed. Thermal conversion is performed in oxygen-free atmosphere in unique construction of pyrolysis chamber which guarantees constant quality of product obtained from the treatment.



The Cooling / Heating System UPK®

UPK® is a continuous cooling conveyor for extracting the char from Biogreen system. The cooling function is accomplished through chilled water or other thermal fluid passage into the screw and double jacket.

The air extraction in the top opening allows the control of the atmosphere conditions above the product: wet extraction, dried air injection etc.

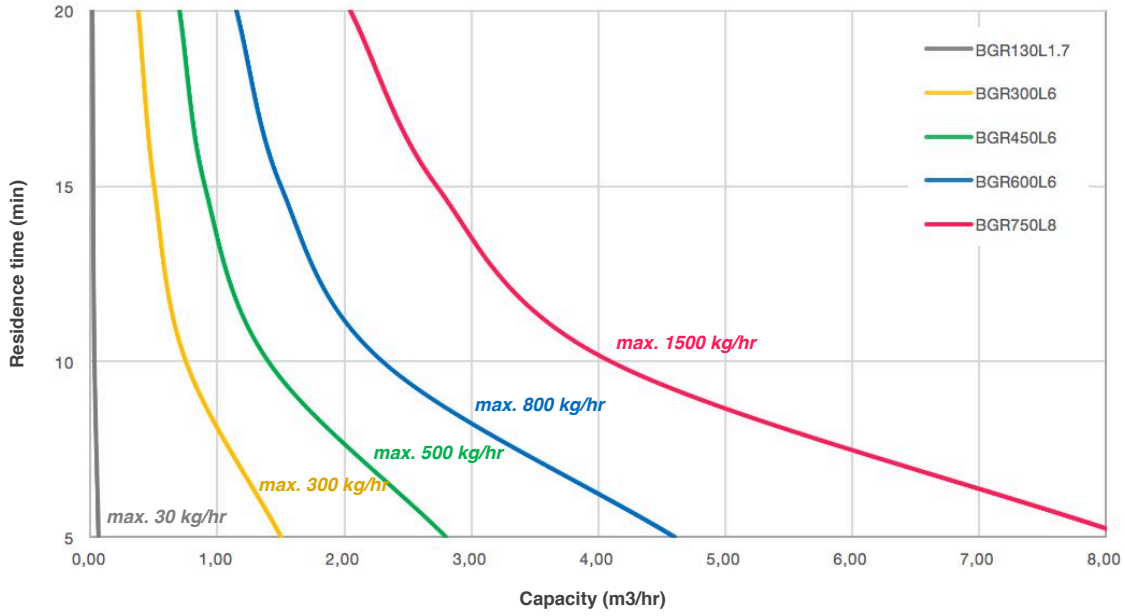


4. MODELS AND CONFIGURATIONS

Biogreen® capacity is linked to the applied treatment time ("residence time") of raw product and it's apparent density (kg/m3). Residence time of material is set up in Biogreen® control panel and regulated by screw rotation speed.

Tables and graphs below are made to provide a guidance on available capacities of equipment and it's linked throughout in **volume and mass of raw material treated**. Due to diversity of feedstock and it's individual behaviour, please consult ETIA representative for the most accurate estimations for your project.

Model		BGR130L1.7 (pilot bench)				BGR300L6				BGR450L6				BGR600L6				BGR750L8			
Residence time	**min.**	**5**	**10**	**15**	**20**	**5**	**10**	**15**	**20**	**5**	**10**	**15**	**20**	**5**	**10**	**15**	**20**	**5**	**10**	**15**	**20**
Volumic flow	l/hr	60	30	20	15	1500	750	500	375	2800	1400	900	700	4600	2300	1500	1150	8200	4100	2730	2050
Capacity at reference density (kg/m3)	100	6	3	2	2	150	75	50	38	280	140	93	70	460	230	152	115	820	410	272	205
	200	12	6	4	3	300	150	100	75	500	280	187	140	800	460	307	230	1500	820	547	410
	300	18	9	6	5	300	225	150	113	500	420	280	210	800	690	460	345	1500	1230	820	615
	400	24	12	8	6	300	300	200	150	500	500	373	280	800	800	613	460	1500	1500	1093	820
	500	30	15	10	8	300	300	250	188	500	500	467	350	800	800	767	575	1500	1500	1367	1025
	600	30	18	12	9	300	300	300	225	500	500	500	420	800	800	800	690	1500	1500	1500	1230



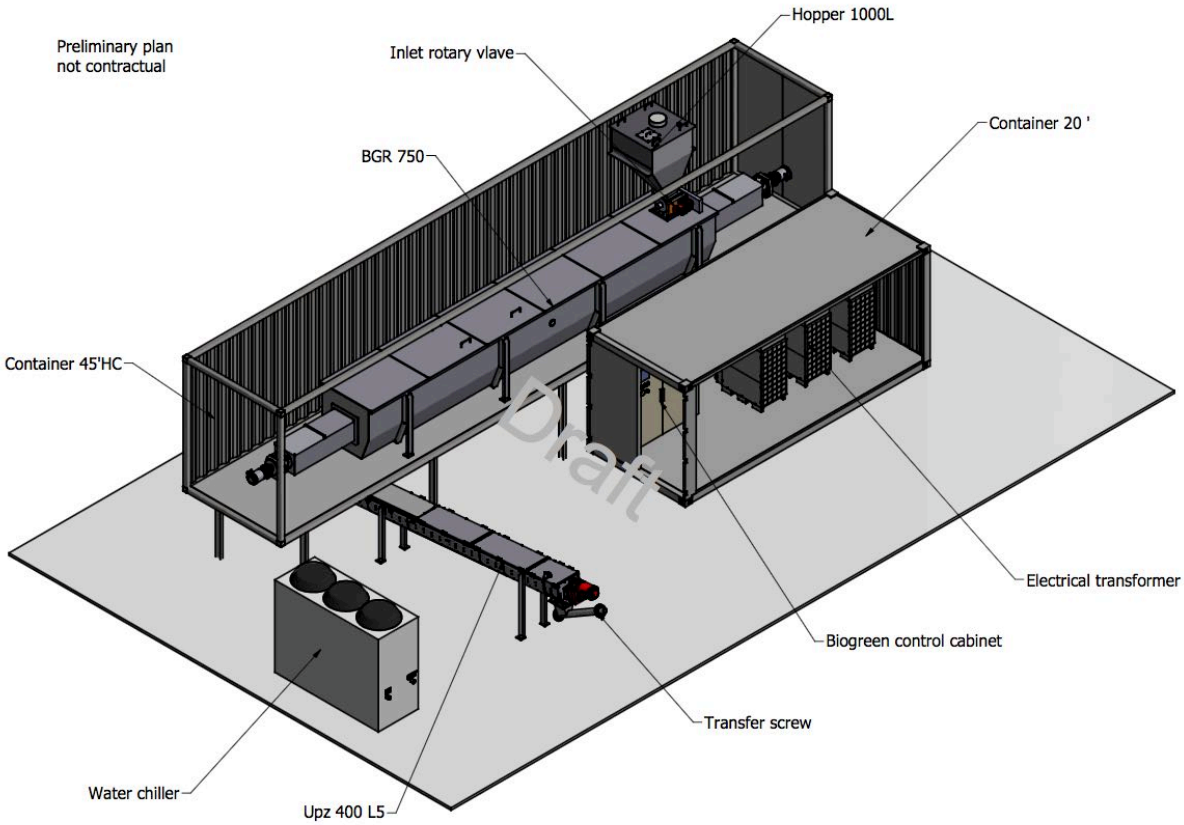
4. LAYOUT AND DIMENSIONS

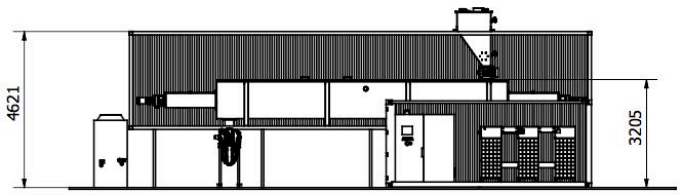
Proposed equipment can be performed in two versions - containerised (CM) equipment and stationary plants (BGR). **Containerised (CM)** units provide several advantages related to quick installation, facilitated transport and modular construction of plant. This type of plant is suitable for fast, often temporary applications designed to be moved or rearranged after a time-period, shipped or stored in long-term. Because of it's portable and standardised construction, BiogreenCM models are also recommended for limited space areas, projects constraining non-interference in local infrastructure, investments requiring no building works or remaining under particular law regulations.

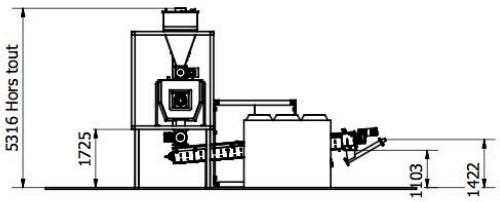
In contrary, the **stationary Biogreen®** offer the possibility to shape the equipment configuration according to local conditions. This type of setup is often consideration for all projects dedicated for long-term operation with sufficient space conditions, i.e. newly designed plants, urban peripheries etc.

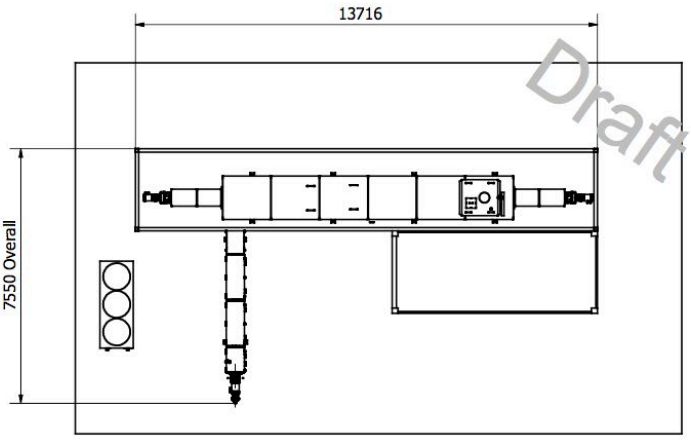
Biogreen® dimensions are linked with size of two core system components: Spirajoule® and char cooler (UPZ), as well as auxiliary components. The UPZ unit dimensions will differ depending on the quantity of char to be cooled.

Below values are meant to provide a guidance for the Biogreen BGR750 system being example of estimated dimensions required for pyrolysis unit and do not include the auxiliaries equipment. Please consult ETIA for the detailed information on system dimensions applicable for your case.









Preliminary plan
not contractual

5. MAINTENANCE

A special attention was paid to the consideration of behaviour in the short, medium and long-term of the implemented equipments during the study and design phases. Biogreen requires periodic maintenance typically related to the use of industrial heat production equipments such as:

- The calibration check of the measuring instruments
- Periodic control of the flue gas composition
- Periodic inspection of the installation

Maintenance activities require:

Regular maintenance

Regular maintenance on the machine shall be held every 15 operating days and includes:

1. Inspection of Spirajoule technical boxes to assure no presence of dust, oil and grease inside.
2. Inspection of the screw inside the technical box and checking if no screw is loosen
3. Inspection of tightening the power supply cables, brush-holders, Spirajoule screw flange connections, bearing nuts
4. Control of the cooling fan filter, deducting in case of necessity.
5. Inspection of the transformer filter and cleaning in case of needed.
6. Inspection of filters located in the control cabinet
7. Lubrication of the rotary airlock chains
8. Control of the flange tightening and gasket
9. Inspection of the nitrogen connections

Quarterly maintenance

Quarterly maintenance on the machine shall be held every 3 months. This maintenance includes the following control procedure:

1. Bearing maintenance (checking the bearing lubrication and lubricating with high temperature grease)
2. Ceramic maintenance (visual control of the ceramic surfaces)
3. Oil motor maintenance
4. Safety water circuit maintenance
5. Nitrogen circuit maintenance
6. Control cabinet ant transformer cleaning
7. Sealing maintenance (control of the conditions on Spirajoule covers, technical boxes, char cooler covers).

Detailed list of global maintenance operations and it's frequencies (weekly, hourly, monthly) are detailed in the operations manual provided together with the system.

6. SAFETY MEASURES

Biogreen system is compliant with Harmonised European Union Standards and produced under the following norms and standards:

- 2006/95/CE Low Voltage Directive
- 2006/42/CE Machinery Directive
- 2004/108/CE EMC Directive

Security of the process is assured through number of measures, including:

- HAZOP analysis of each produced equipment
- software measures: online process monitoring and control of the conditions inside the reactor (temperatures, pressure, rotation speed of motors) connected to the quick response time system of safety response (automatic shutdown, safety shutdown, information on critical errors)
- operation of the pyrolyzer below ambient pressure
- airlocks on the product inlet, gas and char extraction
- short time of emergency stop

In proper operation and maintenance of the plant, there is no risk of explosion and equipment do not generate ATEX zone in the context of the directives. Blanketing with an inert atmosphere (nitrogen) excludes the presence of sufficient O2, necessary for the formation of an explosive atmosphere. Furthermore, the blanketing is guaranteed through oxygen detection. Oxygen concentrations less than 5 vol% are a start-up condition and emergency purge with N2 occurs when O2 > 5 Vol%. Moreover, no electrical ignition sources are present inside the installation. For these reasons, there is no basis for area classification.

7. END NOTES

ETIA's products are provided with CE mark and comply with the provisions of applicable European Union harmonised legislation. Compliance with national, local or federal codes, standards and safety regulations specific to the country of operation must be assured by the customer/end user.

Product described in this technical documentation is intended to be incorporated with other equipment to create a complete system designed to perform the requested application in effective and safe manner.

End user shall be responsible for providing the associated equipment for managing the products of thermal treatment process, as well as carrying out a risk analysis with consideration to the national, local or federal codes, standards and safety regulations which are specific to the country of operation.

This technical documentation contains general information about Biogreen system to assist the potential customer in deciding to undertake a more detailed review of technology. ETIA is continuously working on the further development of it's product and changes of the technological solutions as well as delivery scope are possible. This document therefore should not be treated as the formal offer for equipment.

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