MULTI-WASTE TREATMENT AND VALORISATION BY THERMOCHEMICAL PROCESSES

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PART 1:

THERMOCHEMICAL PROCESSES

Introduction.

- Form of wastes is a major barrier to a rapid shift from fossil to biofuels.
- Unlike gas or liquid, solid wastes cannot be handled, stored, or transported easily.
- This provides a major motivation for the conversion of solid wastes into liquid and gaseous fuels.
- Thermochemical conversion is a high-temperature chemical reforming process that breaks apart the bonds of organic matter and reforms these intermediates into:
    - Solid fraction (biochar).
    - Gas fraction (synthesis gas or syngas).
    - Liquid fraction (highly oxygenated bio-oil).

Introduction.

- Benefits of the thermochemical process:
  - Small footprint.
  - Efficient nutrient recovery.
  - No gas emissions.
  - Short reaction time.
  - Capability of handling a variety of wastes and blends.
- Production of thermal energy is the main driver for this conversion route that has four broad ways:
  - Combustion.
  - Pyrolysis.
  - Gasification.
  - Liquefaction.

Introduction.

Comparative of thermochemical processes:

Process	Temperature (ºC)	Pressure (MPa)	Products
Combustion	700-1400	0.1	Thermal energy
Pyrolysis	400-800	0.1	Biochar Gas Bio-oil
Gasification	500-1300	0.1	Syngas
Liquefaction	250-350	5-20	Liquid biofuel

Combustion.

- Combustion can ideally be defined as a complete oxidation of the fuel.
- Hot gases from the combustion may be used for:
  - Direct heating purposes in small combustion units.
  - Water heating in small central heating boilers.
  - Water heating in larger central heating systems.
  - Heat water in a boiler for electricity generation in larger units.
  - As a source of process heat.

Combustion. Influencing factors.

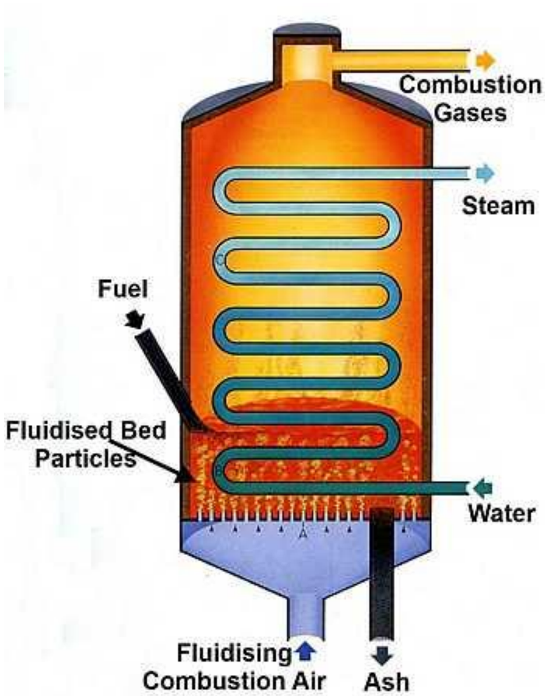


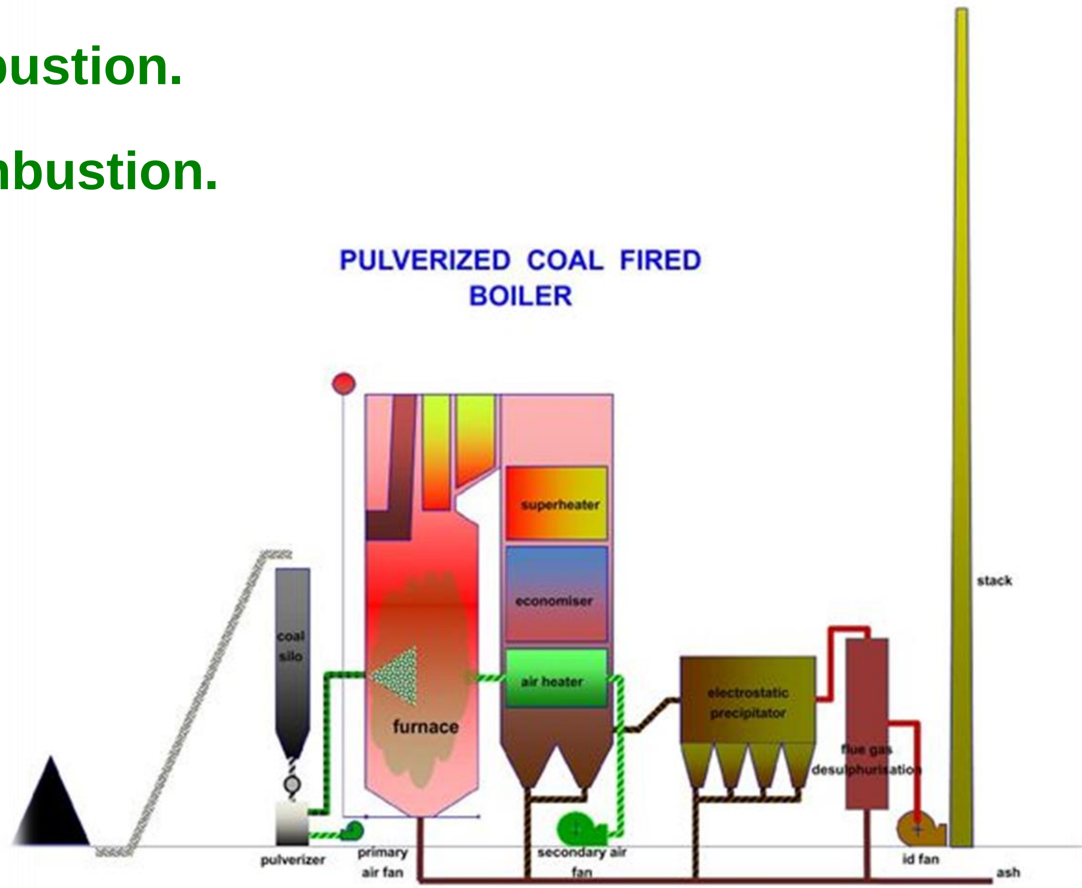

- Air preheating.
- Moisture content.
- Ash.
- Particle size and excess air.
- Raw material (co-combustion).
  - Co-combustion is the waste and coal combustion simultaneously and represents:

    - Low-risk.
    - Low-cost.
    - Sustainability.
    - Renewable energy option.
    - Reduction in net CO_2 emissions.
    - Reduction in SO_x and of NO_x emissions.

Combustion. Technologies.

- **Technologies available for waste combustion:**
  - **Fixed bed combustion.**
  - **Fluidised bed combustion.**
  - **Pulverised bed combustion.**





Pyrolysis.

- Thermal cracking of waste feedstock without or with limited supply of oxidant-yielding volatile products and solid residue.
- Temperature operation ranges: 400–800 ºC.
- Three process products are obtained:
    - Gas.
    - Liquid (bio-oil).
    - Solid (char or biochar).
- Two main processes for waste pyrolysis:
    - Fast pyrolysis.
    - Slow pyrolysis.

Pyrolysis.

- Relative amount of each product depends on operating parameters.

Effect of operating variables on pyrolysis yield.

Yield maximised	Temperature	Heating rate	Gas residence time
Biochar	Low	Slow	Long
Bio-oil	Low	High	Short
Gas	High	Low	Long

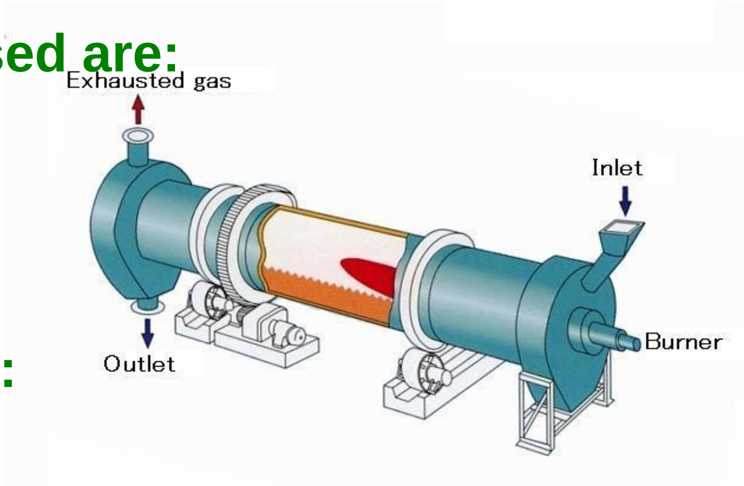
Pyrolysis. Influencing factors.

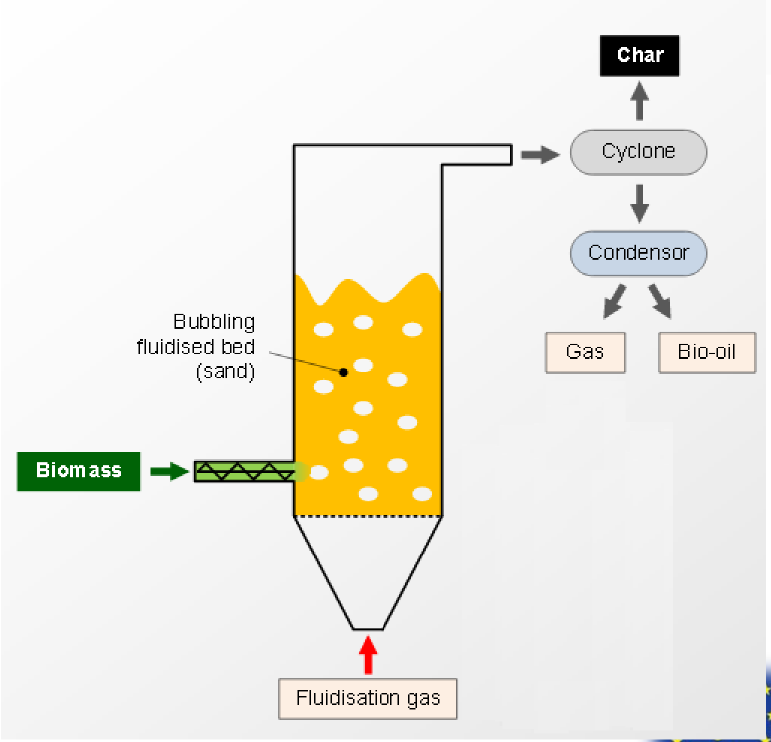
- Temperature.
- Particle size.
- Rate of waste heating.
- Sweeping gas flow rate.
- Mineral matter contents.
- Initial moisture.
- Catalyst.

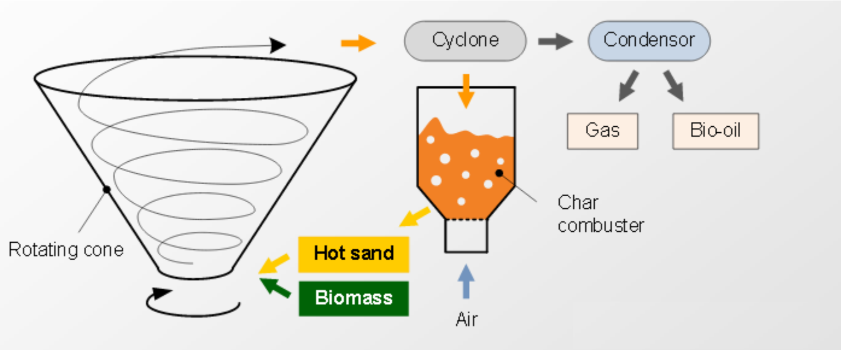
Ca Mg Na K Cl

Pyrolysis. Technologies.

- In slow pyrolysis, typical technologies used are:
  - Fixed bed reactor.
  - Rotary kiln reactor.
- In fast pyrolysis, typical technologies are:
  - Fluidised bed reactor.
  - Rotating cone reactor.
  - Ablative reactor.
  - Vacuum reactor.







Gasification.

- Thermochemical process that converts carbonaceous feedstock into a fuel gas through partial oxidation.
- The fuel gas generated includes:
  - Carbon monoxide (CO).
  - Hydrogen (H_2).
  - Carbon dioxide (CO_2).
  - Methane (CH_4).
  - Light hydrocarbons.

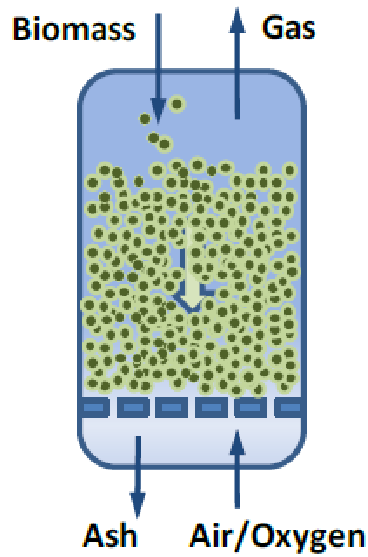
- This gas mixture can be subsequently used to produce:
  - Electricity (gas engine or turbine).
  - Heat.
  - Synthesis of various products (catalytic process).

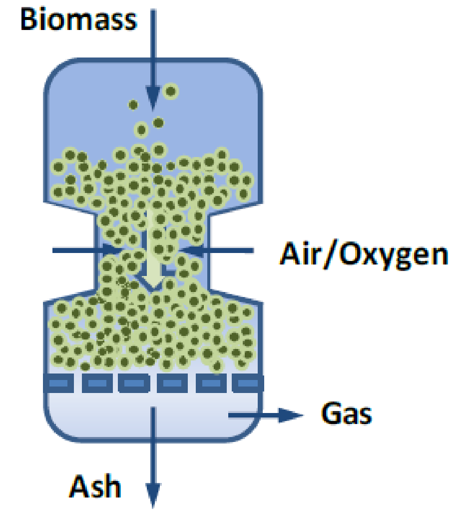
Gasification. Influencing factors.

- Feed particle size.
- Moisture.
- Gasifying agent.
- Equivalence ratio (ER).
- Temperature.

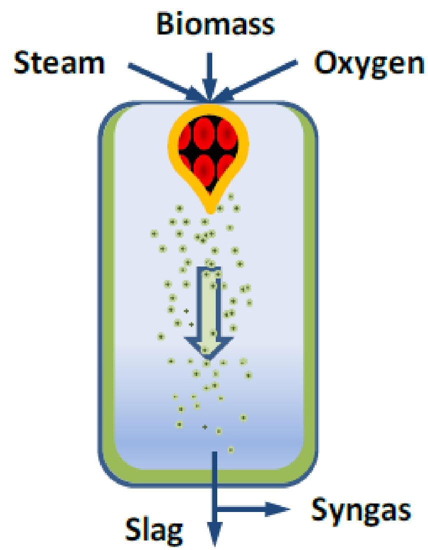
Gasification. Technologies.

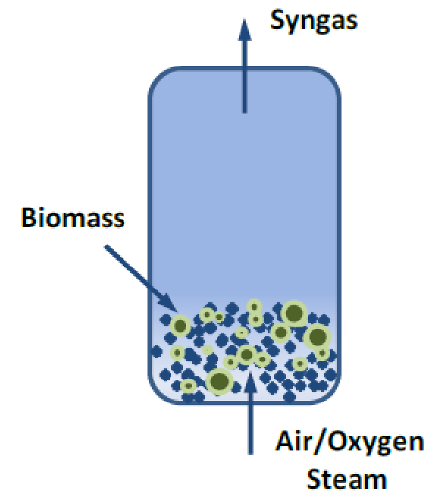
- Technologies available for waste gasification:
  - Fixed bed or moving bed.
    - Updraft.
    - Downdraft.





  - Fluidised bed.
  - Entrained bed.





Liquefaction.

- **Liquefaction is a low temperature and high pressure thermochemical process during which waste is broken down into fragments of small molecules in water or another suitable solvent.**
- **Light fragments, which are unstable and reactive, can then repolymerise into oily compounds with various ranges of molecular weights.**
- **Hot compressed water is a powerful hydrothermal media for depolymerisation and repolymerisation of lignins, celluloses, lipids, and proteins into biocrude oil, water soluble organics, gas and biochar.**

Liquefaction. Influencing factors.

- Raw material type.
- Temperature.
- Pressure.
- Reaction time.
- Solvent type.
- Catalyst.

PART 2:

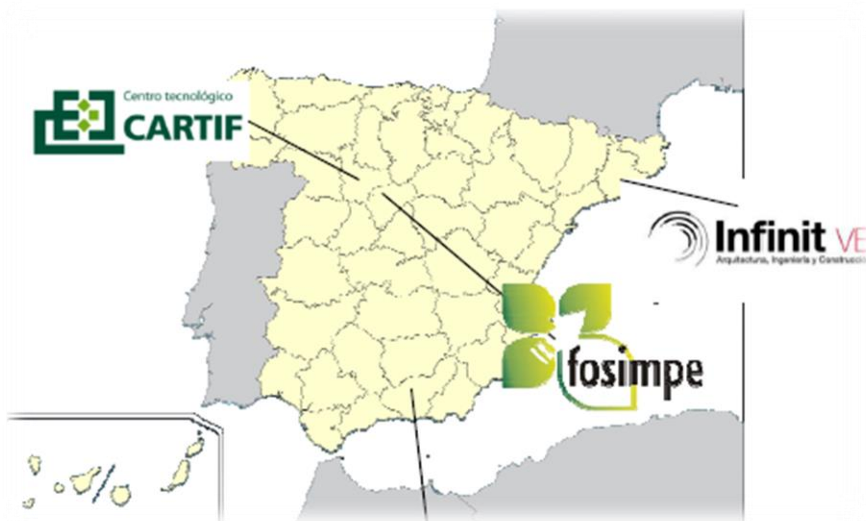
NEW TENDENCIES FOR WASTE TREATMENT

New tendencies for waste treatment.

- Two projects use thermochemical conversion technologies to treat a variety of waste with the focus on the final valorisation of these residual streams.
  - REVAWASTE Project.
  - EUCALYPTUS ENERGY Project.
- Both projects use pyrolysis as thermochemical process.
- Pyrolysis technology was selected as the most appropriate technology because of:
  - It allows to treat a variety of waste.
  - Versatile and easy to combine with other technologies.
  - It allows to valorise by-products of the process.

REVAWASTE Project. Introduction.

- **REVAWASTE Project.**
- **Project funded by EC into LIFE + Program (LIFE12 ENV/ES/000727).**
- **Consortium is composed by:**
  - **Fundación CARTIF (RTD, Spain) (Coordinator).**
  - **Infinit VE (SME, Spain).**
  - **Fosimpe (SME, Spain).**



REVAWASTE Project. Purpose.

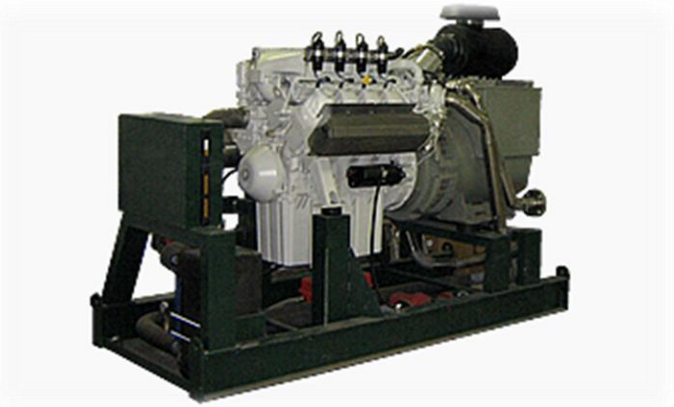
- The general aim of the project is the sustainable management of a broad spectrum of wastes in a integrated plant.
- Wastes treated in the plant are:
    - Biomass.
    - Non-recyclable fraction proceeding from waste treatment plants.
    - Agro-food waste (including manure).

REVAWASTE Project. Purpose.

- The objective of the project is reached by means of technological development and practical application of the “mixed plant” concept.
- The “mixed plant” is the integration in the same plant of the different treatment processes.
- This development supports a new waste management strategy (2008/98/ CE Directive), based on:
  - Separation.
  - Pre-treatment.
  - Recycling.
  - Valorisation steps.

REVAWASTE Project. Purpose.

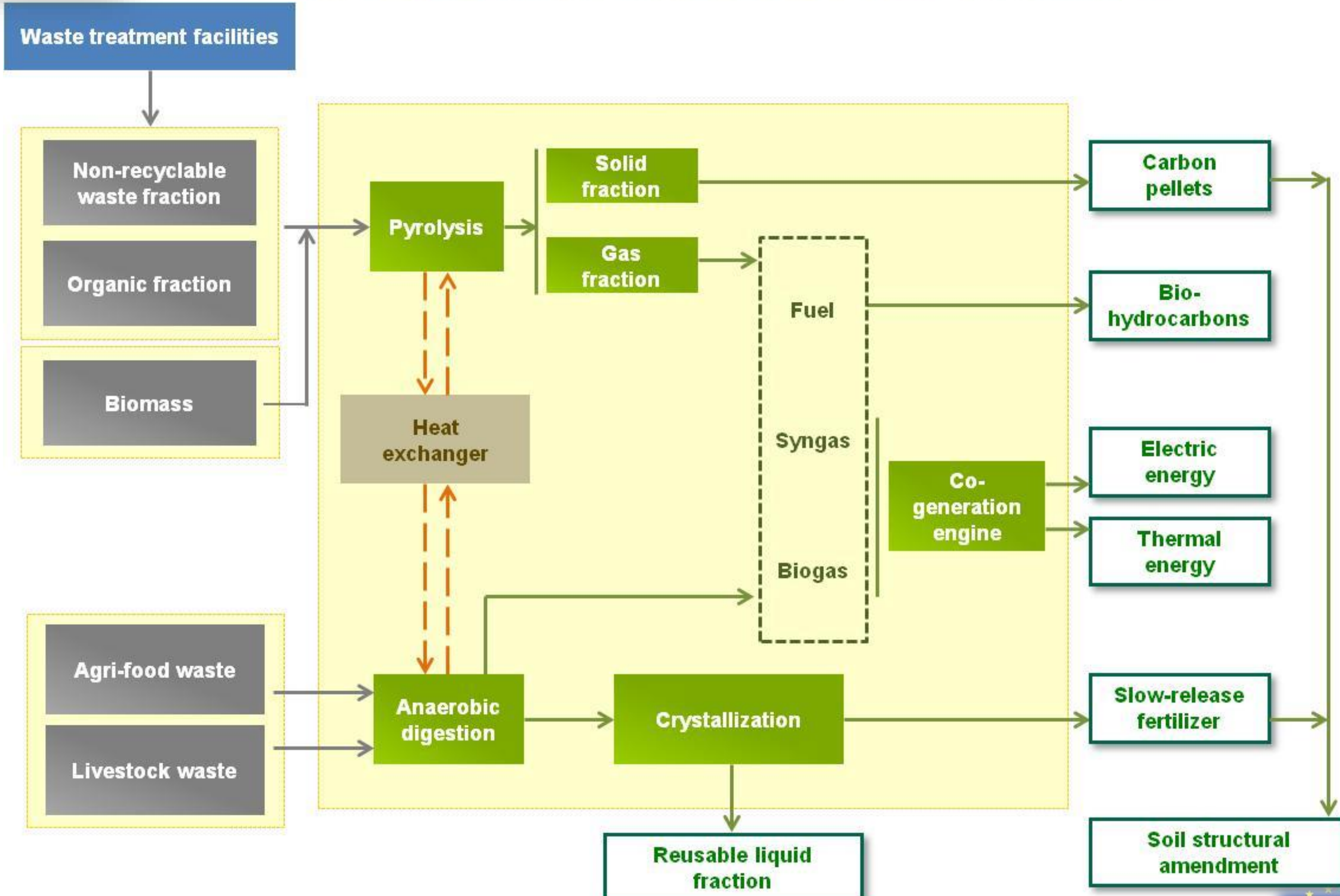
- In order to valorise in a joint the wastes, two different processes have been integrated:
  - Anaerobic digestion system (transformation of biodegradable organic waste into biogas).
  - Low-temperature pyrolysis (valorisation of the non-recyclable plastic waste fraction and biomass).
- Biogas and pyrolysis gas will be used as fuel in an adapted co-generation engine.



REVAWASTE Project. Purpose.

- To close the cycle with a minimun environmental impact:
  - Digestate generated in the anaerobic reactor will be valorise as slow-release fertiliser (struvite).
  - Solid fraction obtained in the pyrolysis process will be transformed into carbon pellets.
  - Liquid fraction obtained during pyrolysis gas distillation process will be valorise as biofuel.

REVAWASTE Project. Process integration.



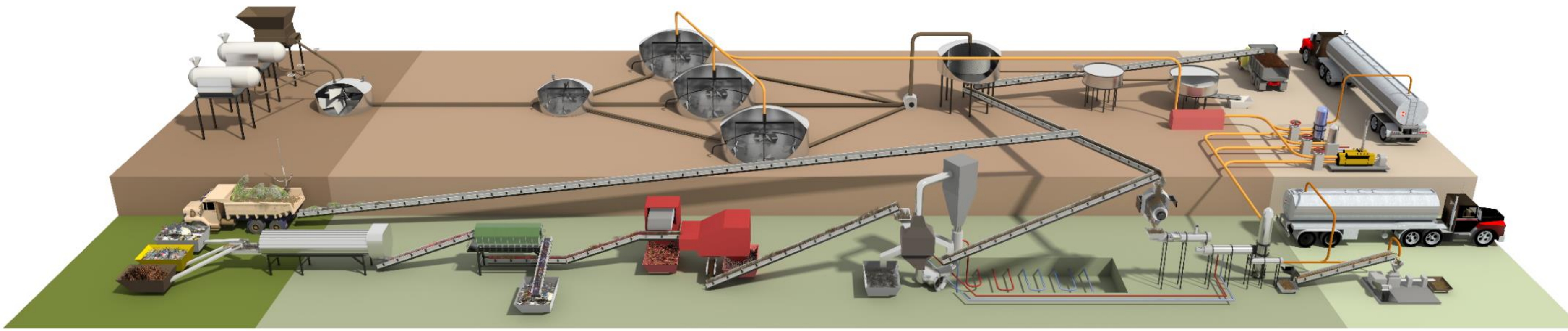
Integrated “mixed plant” flow chart.

REVAWASTE Project. Process integration.

Raw materials anaerobic digestion process

Anaerobic digestion

Anaerobic digestion products



Raw materials pyrolysis process

Pyrolysis

Pyrolysis products

Lay-out “mixed plant”.

EUCALYPTUS ENERGY Project. Introduction.

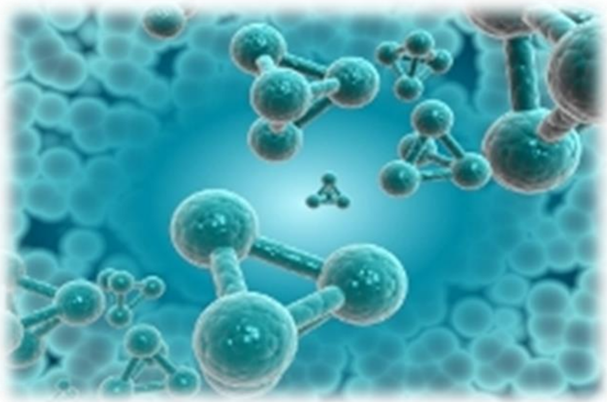
- Project funded by EC into LIFE + Program (LIFE 12 ENV/ES/000913).
- Consortium is composed by:
  - Ingeniería y Manutención Asturiana, S.A. (SME, Spain) (Coordinator).
  - CPL Industries Limited (SME, UK).
  - Fundación CARTIF (RTD, Spain).
  - Asociación Asturiana de Empresarios Forestales y de la Madera (SME, Spain).

- The general aim of the project is the design and construction of a pilot plant for the production of electrical energy by pyrolysing cut Eucalyptus waste.

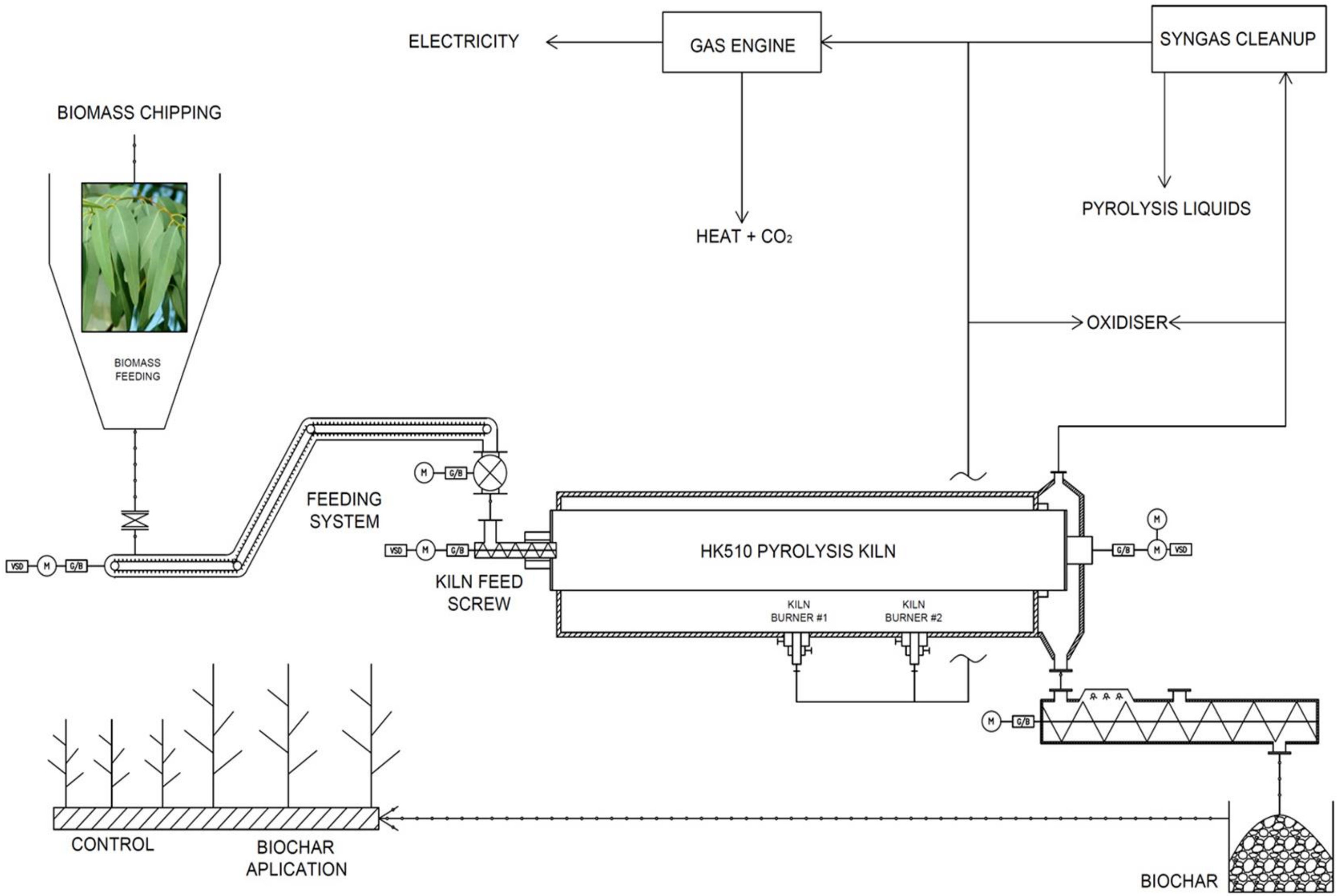
- **Actions of the project:**
  - **<u>Design, construction and operation of pilot plant.</u>**
  - **<u>Integration of the project technologies</u>: This action is critical for the sucess of the project. All the systems and equipment design for the partners need to be coordinated to construct a fully operational plant.**
  - **<u>Biochar aplication and field experiments</u>: Biochar will need to be applied before the plantation of eucalyptus in the field and data from the experiments such as biomass production will be collected.**

EUCALYPTUS ENERGY Project. Purpose.

- The process has a minimun environmental impact:
  - Gas fraction of the pyrolysis process will be used to produce electricity.
  - Solid fraction obtained in the pyrolysis process will be utilised as a carbon abatement technology or as a biofuel.
  - Liquid fraction obtained during gas cleanup process will be valorise as an alternative source of fuel and chemicals.



EUCALYPTUS ENERGY Project. Process.



"Forest Integrated Wood Processing Plant" flow chart.

Conclusions.

- Thermochemical conversion processes have, all of them, the capability of converting waste into value-added products as
  - Gaseous fuels.
  - Combustible oils or chemicals.
  - Solids soils amendment.

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THANK YOU VERY MUCH FOR YOUR ATTENTION

IF YOU HAVE ANY QUESTION, DO NOT HESITATE TO CONTACT ME.

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