The theory, operation and current status of biogas and biomass air gasification technologies: A case study of the University of Fort Hare Projects

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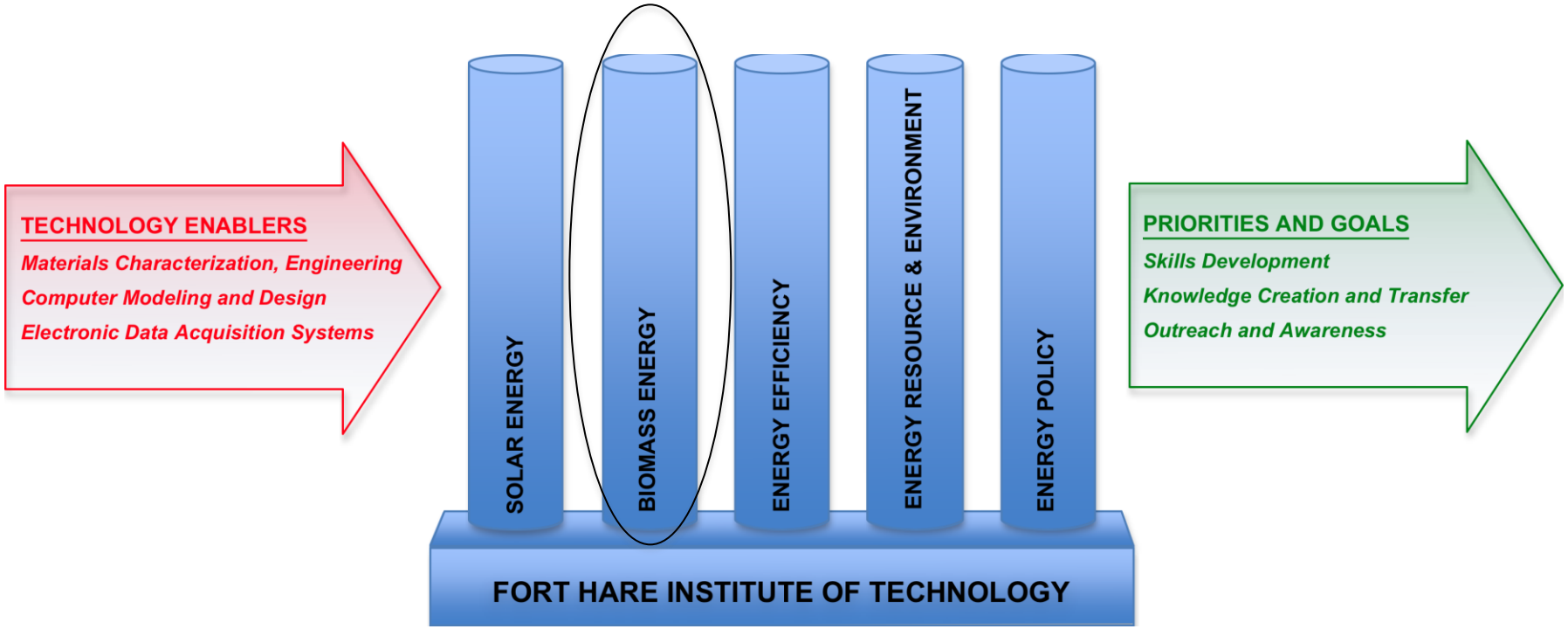
OVERVIEW OF RESEARCH AT FHIT



Biogas digester types

- Biogas produced in anaerobic digesters consists of methane (50-80%), carbon dioxide (20-50%) and trace levels of other gases such as hydrogen, carbon monoxide, nitrogen, oxygen and hydrogen sulphide.

- Anaerobic digesters are made out of concrete, steel, bricks or plastic. They are shaped such as troughs, basins or ponds, and may be placed underground or on the surface depending on the design and climatic conditions of an area.

- There are two basic types of digesters, which are batch type and continuous type.

- There are three types of continuous digesters, these are: Vertical tank systems, horizontal tank or plug-flow systems and multi tank systems.

The digestion process

- Anaerobic decomposition occurs in three basic stages as a result of the activity of a variety of microorganisms. Initially, a group of microorganisms converts organic material into a form that a second group of organisms utilizes to form organic acids and complete the decomposition process.

- A number of factors affect the rate of digestion and biogas production. The most important is temperature.

- Anaerobic bacteria communities can endure temperatures ranging from below freezing to above 57 ^{o}C, but they thrive best at temperatures of about 37^{o}C (mesophillic bacteria) and 55^{o}C (thermophillic bacteria).

- Bacteria activity, and thus biogas production, falls off significantly between 39^{o}C and 51^{o}C and gradually from 35^{o}C to 0^{o}C.

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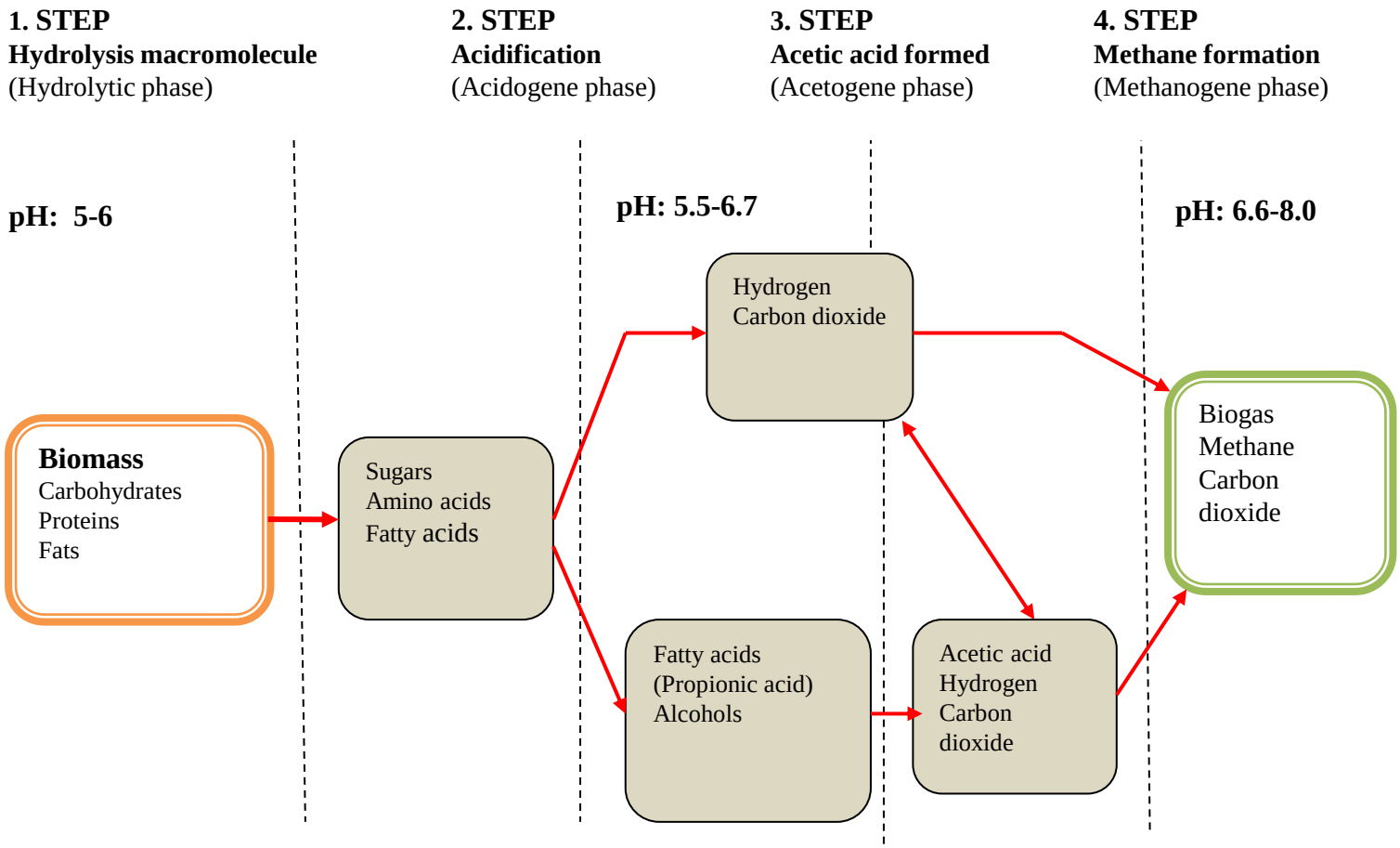
The digestion process

- **Hydrolysis** is an enzyme mediated stage where insoluble organic compounds such as proteins, fats, lipids and carbohydrates are converted into soluble organic components such as amino acids, fatty acids, monosaccharides, and other simple organic compounds.
- **Acidogenesis or fermentation** is the next step where soluble compounds produced in the first stage are further degraded resulting in the production of carbon dioxide (CO_2), hydrogen (H_2), organic acids, alcohols and some organic sulphur compounds.
- **Acetogenesis** is the third stage of acetic acid formation (acetogenesis) combines the prior acidification with methane formation. The starting substrates are a number of final products from the acidification phase. Examples include, chain fatty acids, propionic acid, polymer substrates (carbohydrates, fats, proteins) and butyric acid. Together with lactic acid, alcohols and glycerol, these substrates are converted by the acetogenic micro-organisms into acetic acid, hydrogen and carbon dioxide
- **Methanogenesis:** Methanogens convert the acetate and hydrogen to methane and carbon dioxide. Methanogenic bacteria are divided into three categories. Hydrogenotrophic methanogens use hydrogen to convert carbon dioxide to methane. Acetotrophic methanogens split acetate into methane and carbon dioxide. Finally, methylotrophic methanogens produce methane directly from methyl groups, such as methanol, and mono-, di-, and trimethylamines.

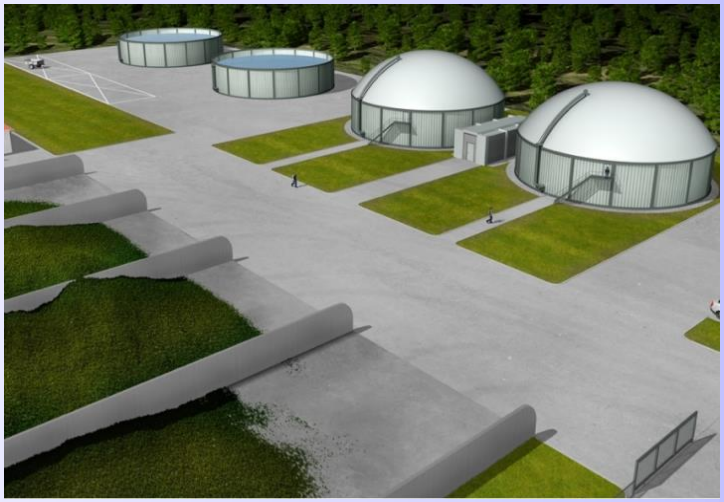
The digestion process



Energy from biogas

- Approximately 1.15 kg of organic waste provides 1 m^3 of biogas, equivalent of 1.7 kWh of energy.

- The energy can be used for direct heating or power generation purposes.



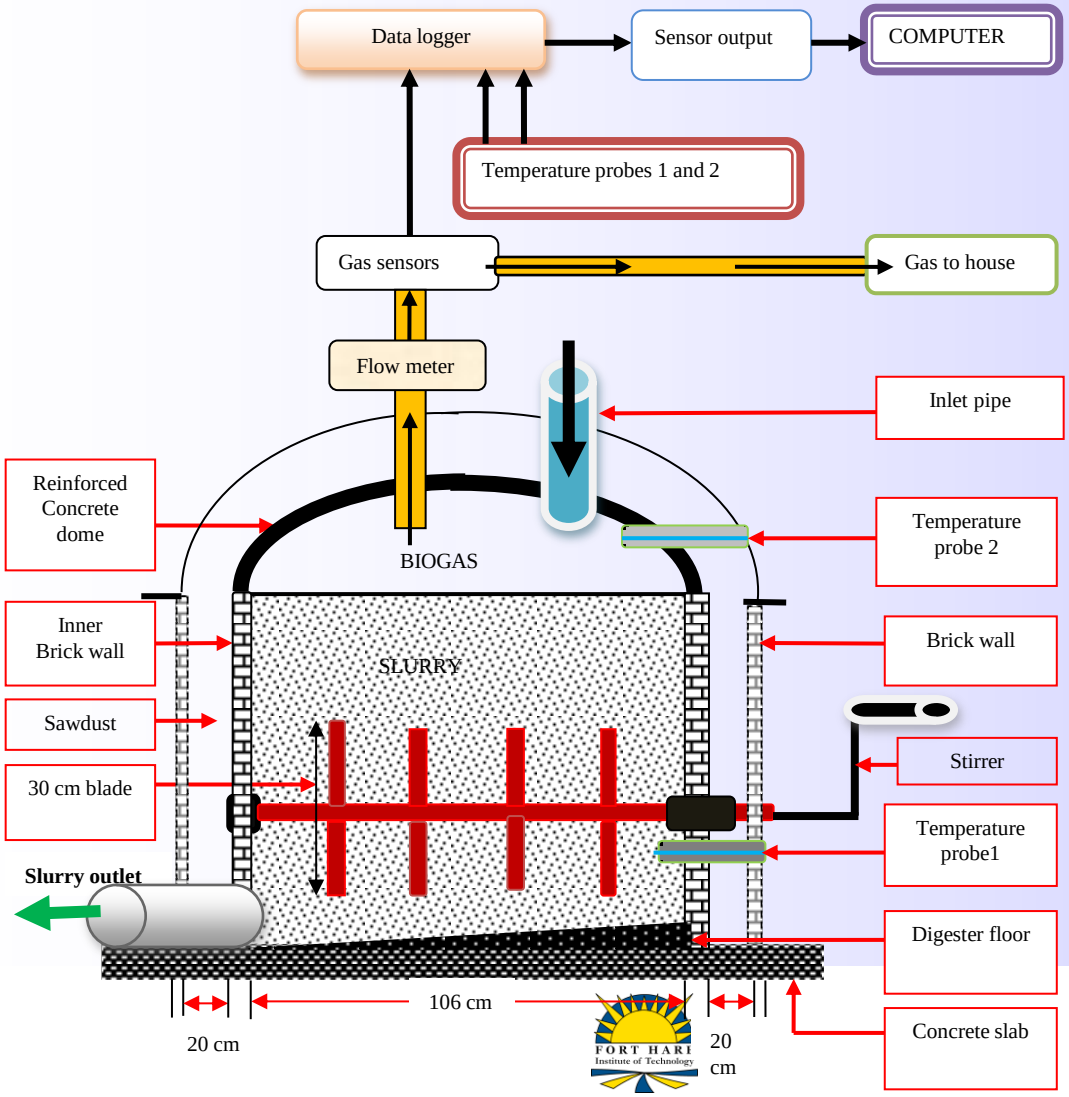
Biogas digesters installations at UFH

The research is focused on:

- Design, installation and performance monitoring of biogas digesters.
- **5** biogas digesters installed at Fort Cox college, Melani village and UFH.
- **110** digesters planned for Nkonkobe municipality-implementation imminent.
- At least 4 digesters planned for schools in Chris Hani District Municipality
- Demonstrate the use of biogas technology as a cheap and sustainable option.

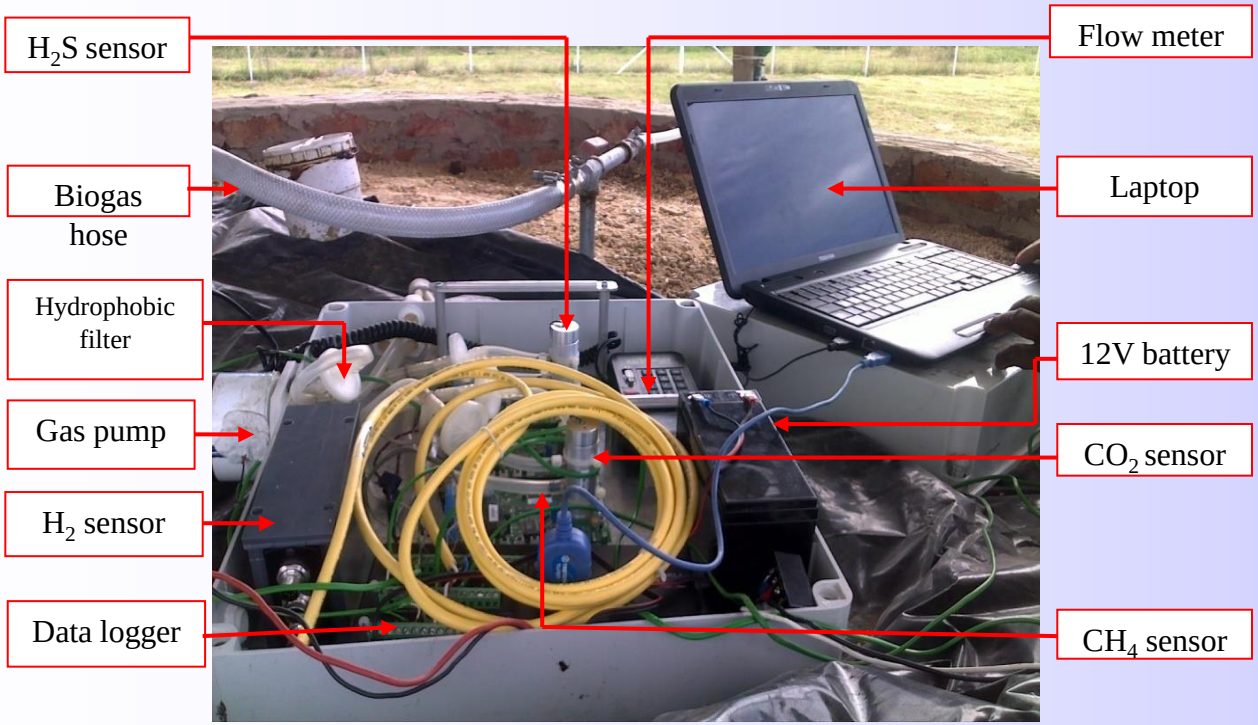
Biogas digesters research activities

- Design, installation and performance monitoring



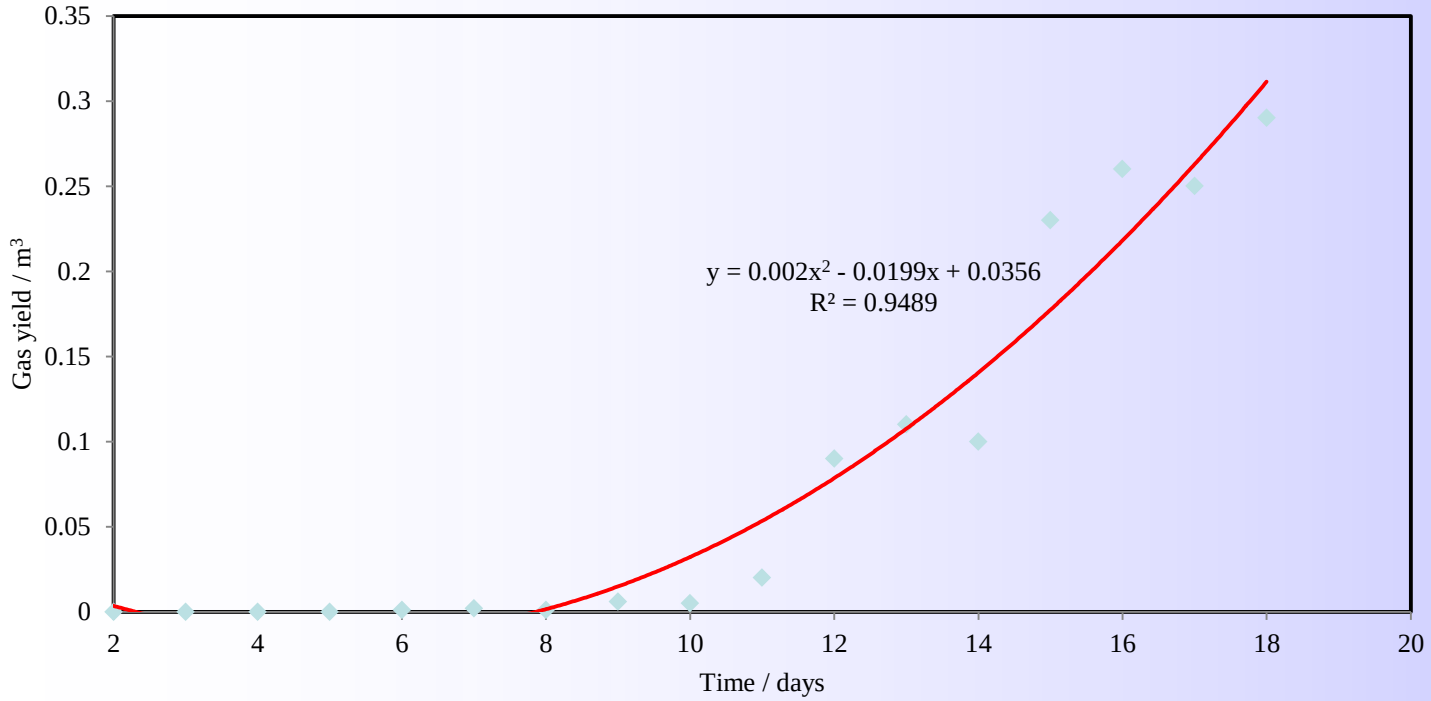
Biogas digesters research activities

- Design, installation and performance monitoring



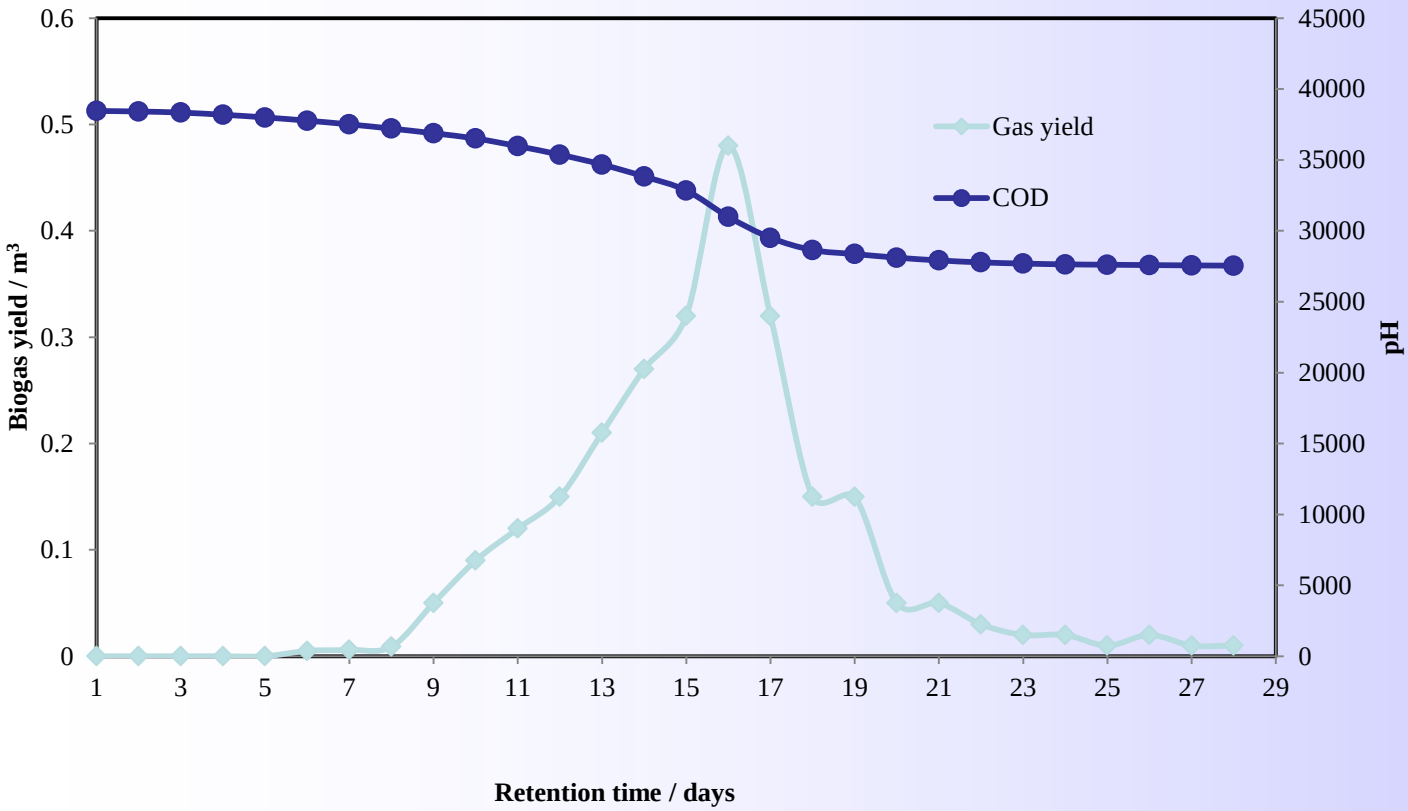
Biogas digesters research activities

- Biogas yield from cowdung before digester insulation



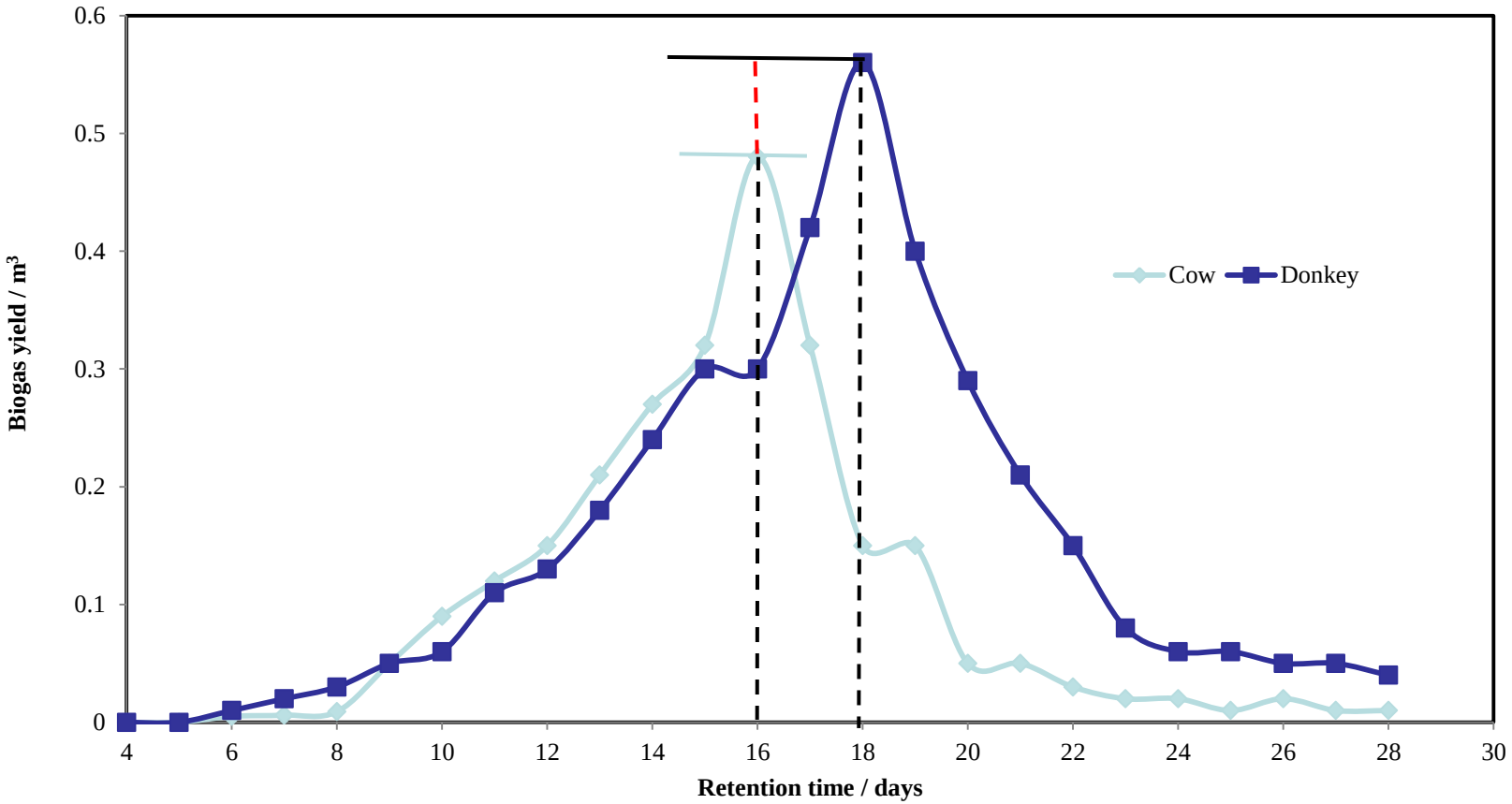
Biogas digesters research activities

- Biogas yield from cow dung vs COD concentration



Biogas digesters research activities

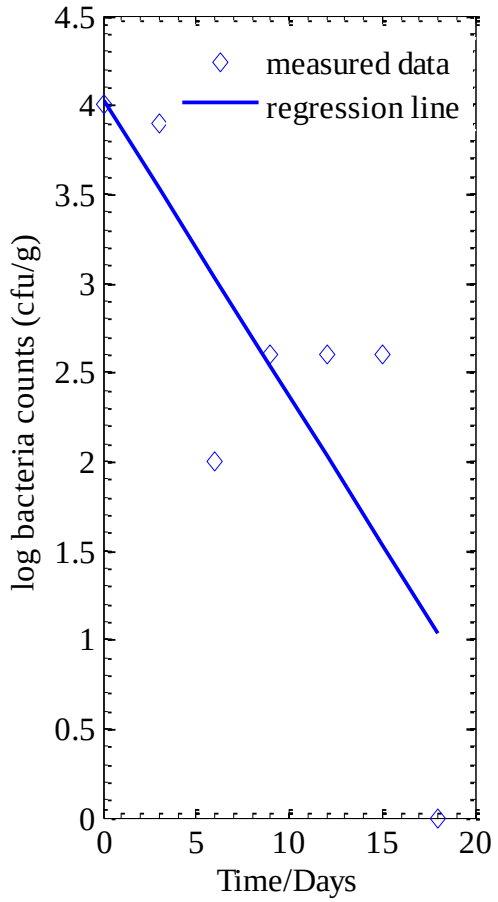
- Biogas yield from cow dung and donkey dung



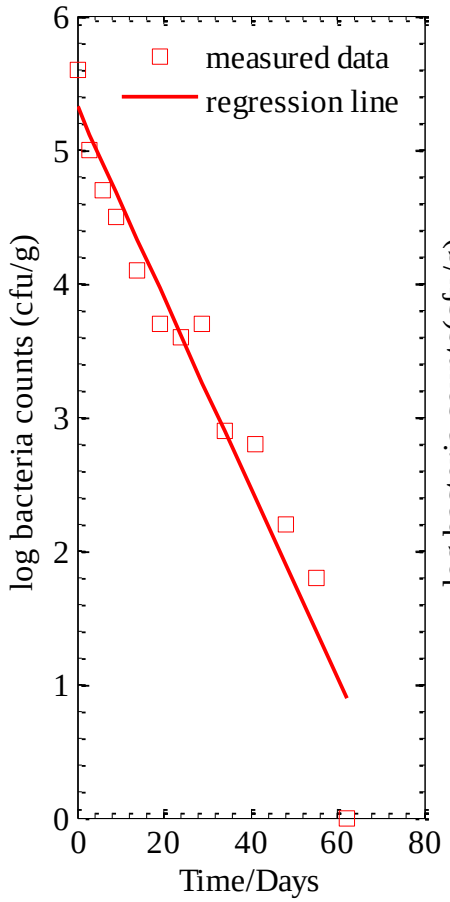
Biogas digesters research activities

- Bacteria activity in cowdung
  - Bacteria that has been well documented in cow manure include *Salmonella Sp*, *Escherichia coli* and *Camphilobacter* species.
  - These are associated with human gastrointestinal infection.

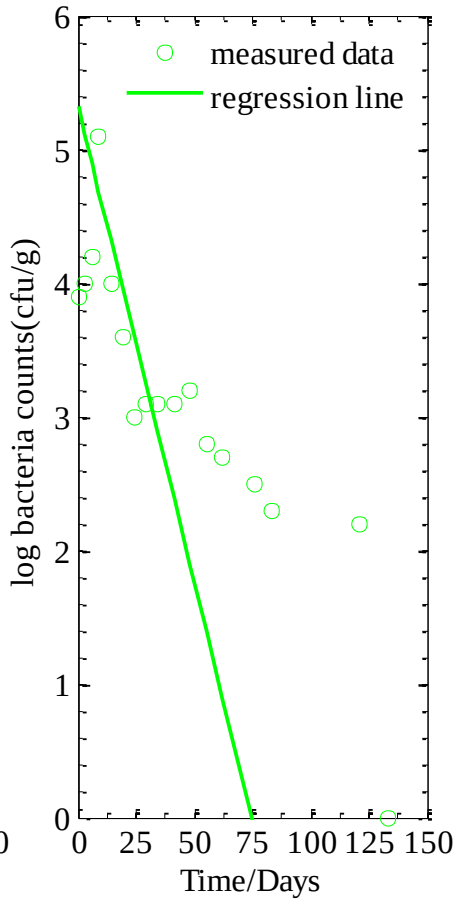
(**a**) Reduction of *Campylobacter* sp counts with retention time. (**b**) Reduction of *E. coli* counts with retention time. (**c**) Reduction of *Salmonella* sp counts with retention time.



(**a**)



(**b**)



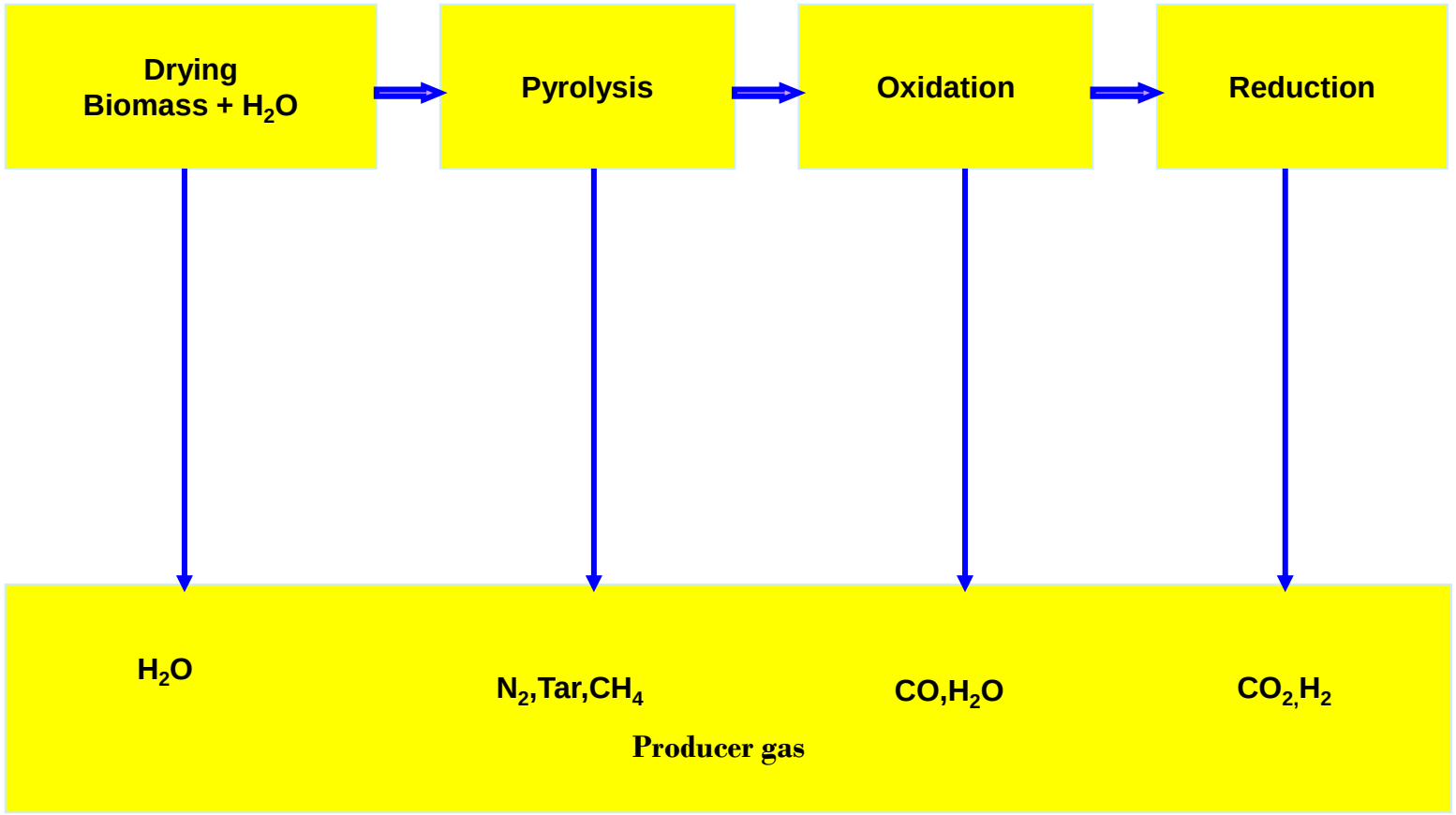
(**c**)

Digesters at UFH

BIOMASS GASIFICATION

- Biomass gasifier converts wood and wood waste into charcoal giving gas as a by-product.
- The gas is a mixture of CO_2, CH_4, H_2, CO, H_2O and N_2.
- It has a heating value of 3-6MJ/kg and is used for heating and electricity generation.
- The University of Fort Hare installed a150kVA System Johanson Biomass Gasifier at Melani village for powering a community bakery and for research purposes.

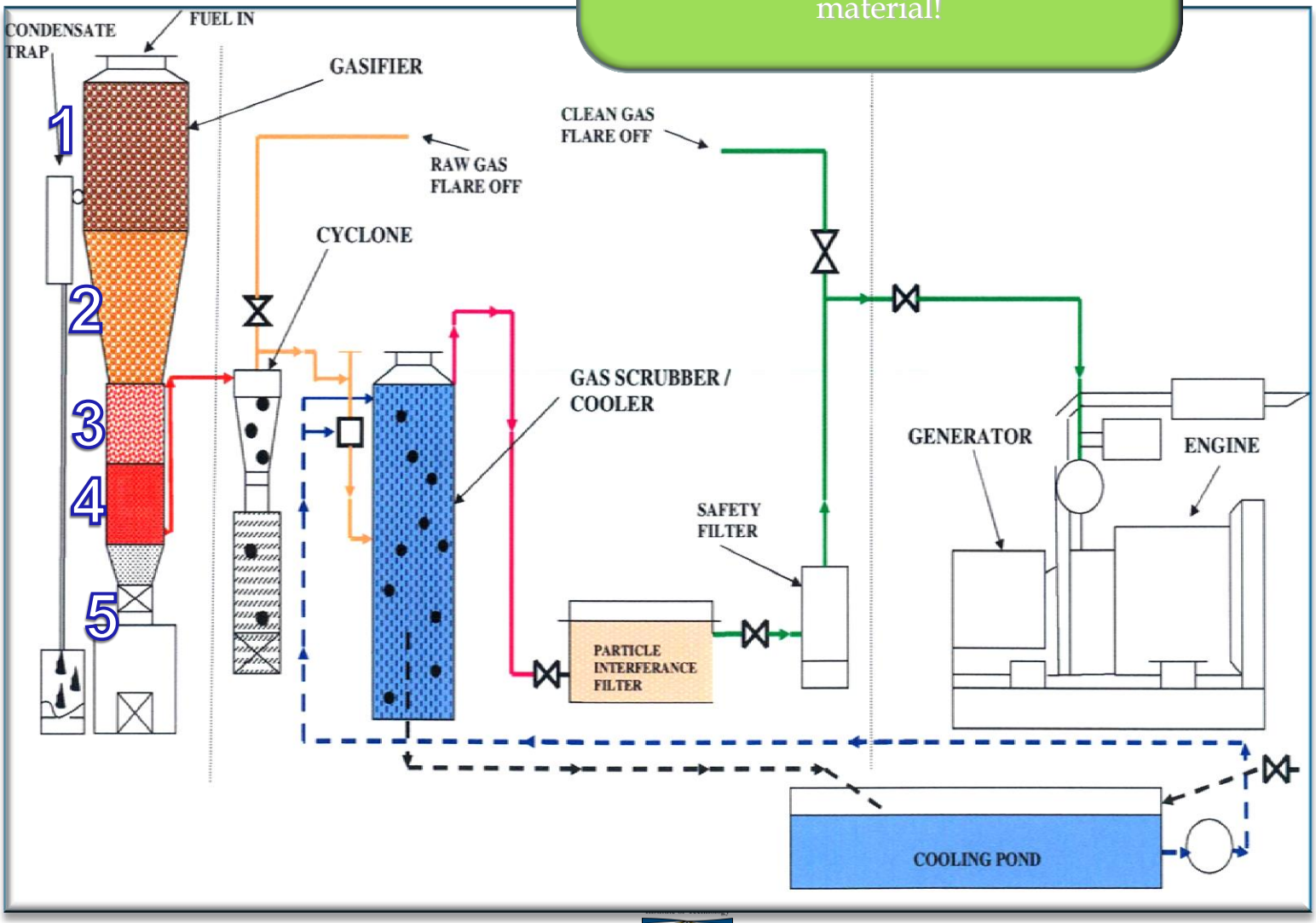
Gasification process



THE PROCESS

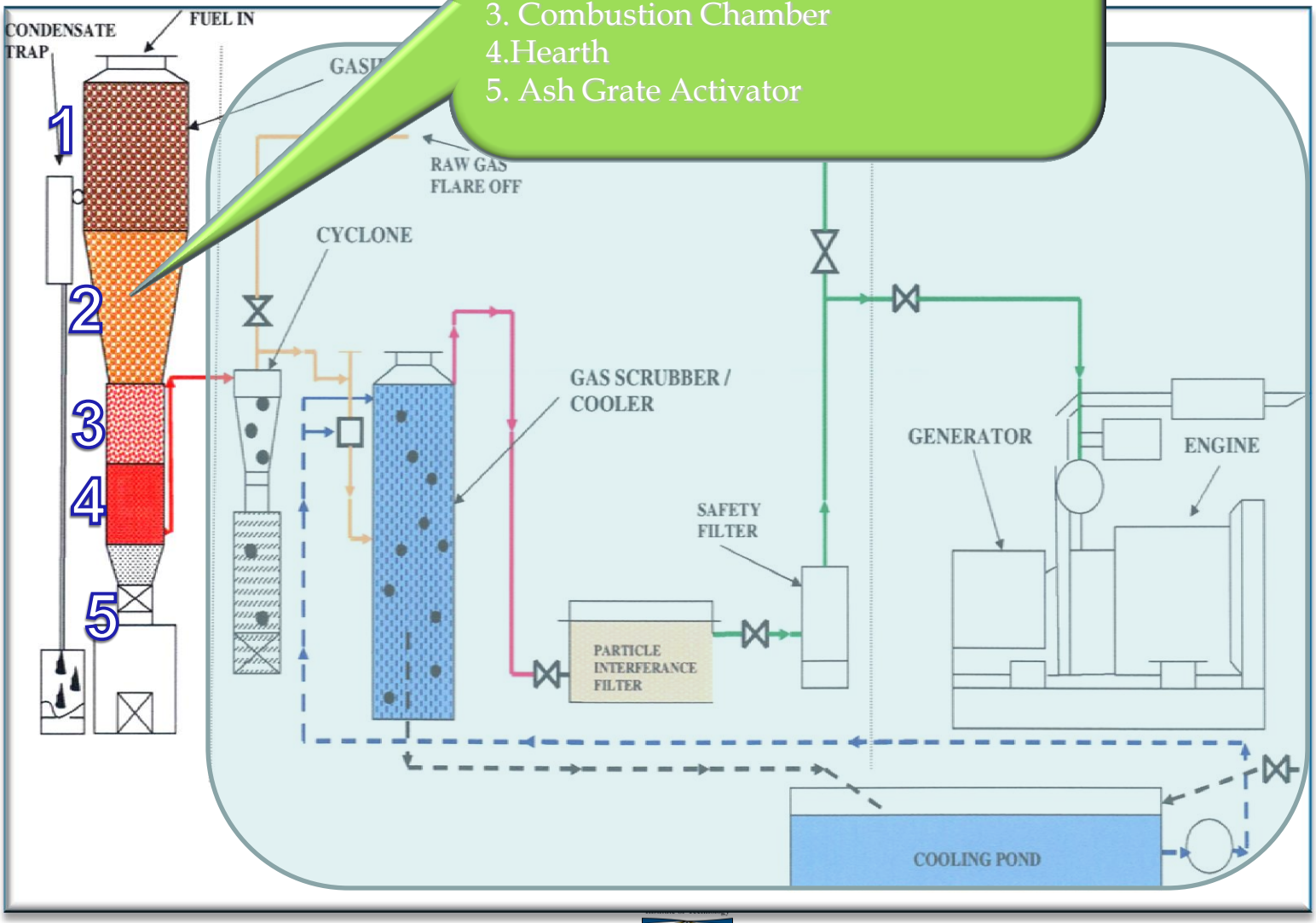
The Gas Producer

The pollution-free answer to providing inexpensive energy through consumption of Bio-mass material!



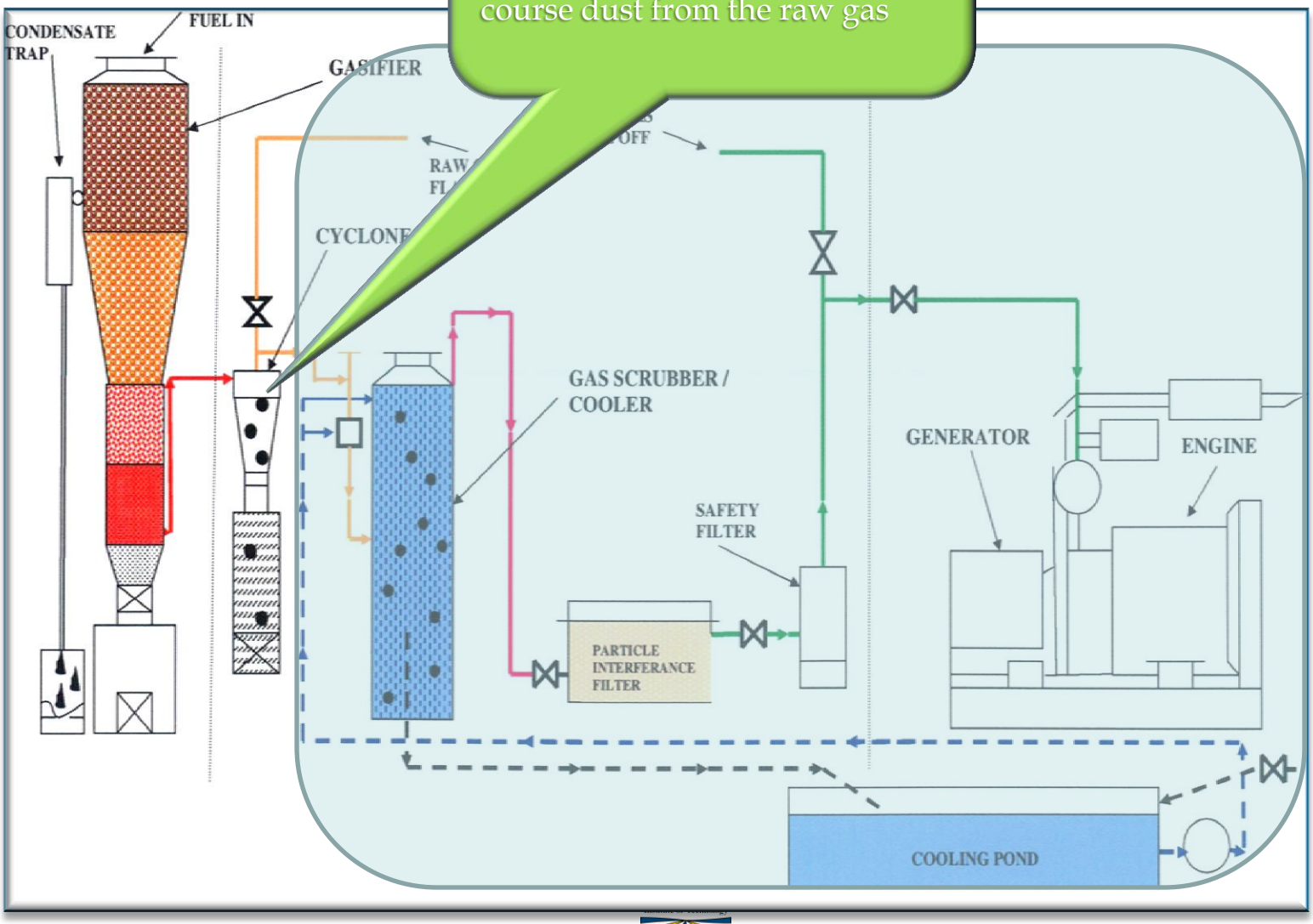
Gasifier

1.Fuel Compartment with Condensate trap
2.Inverted Reduction Cone
3. Combustion Chamber
4.Hearth
5. Ash Grate Activator



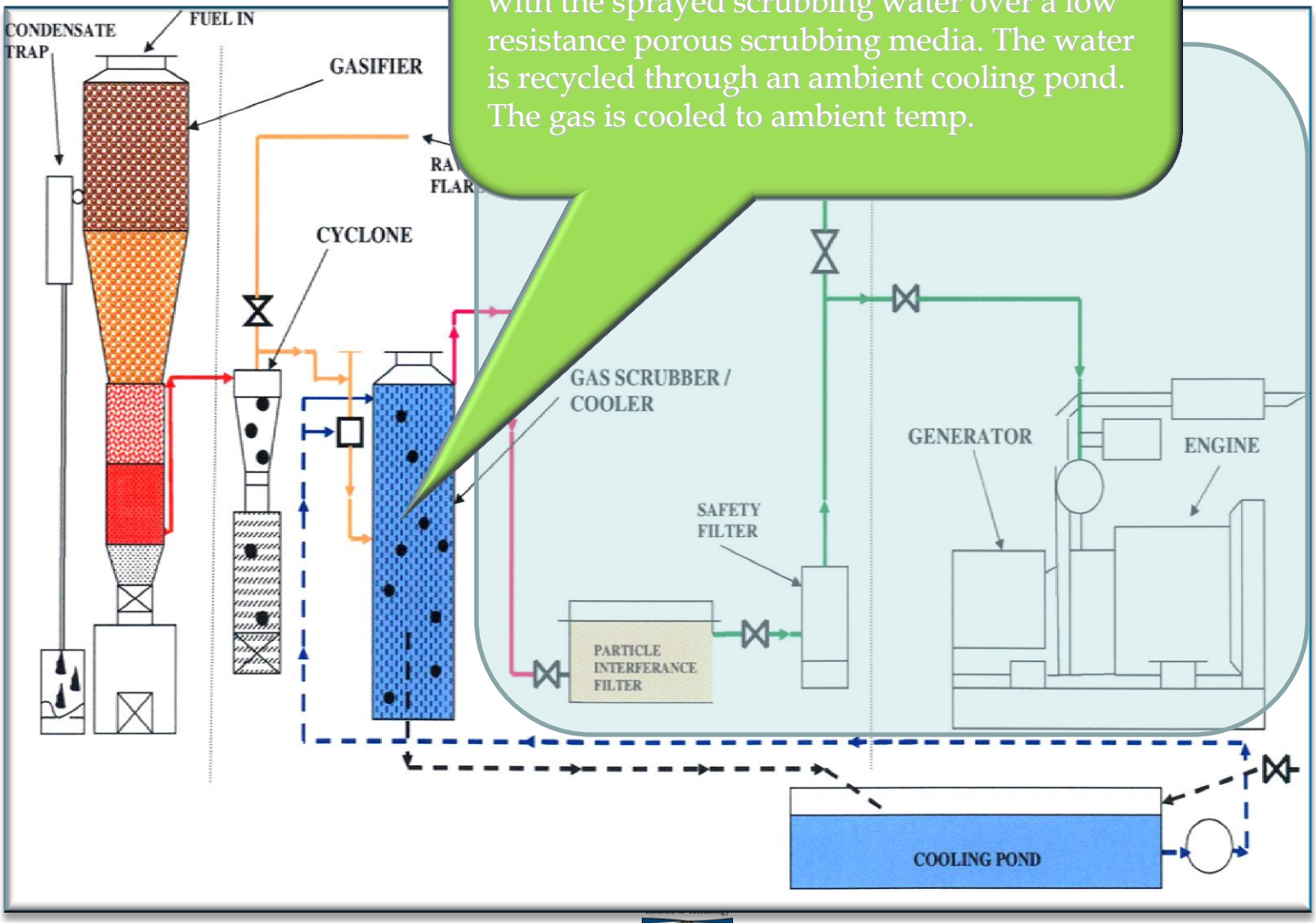
The Cyclone

The Raw Gas is passed through the Cyclone, which removes the course dust from the raw gas

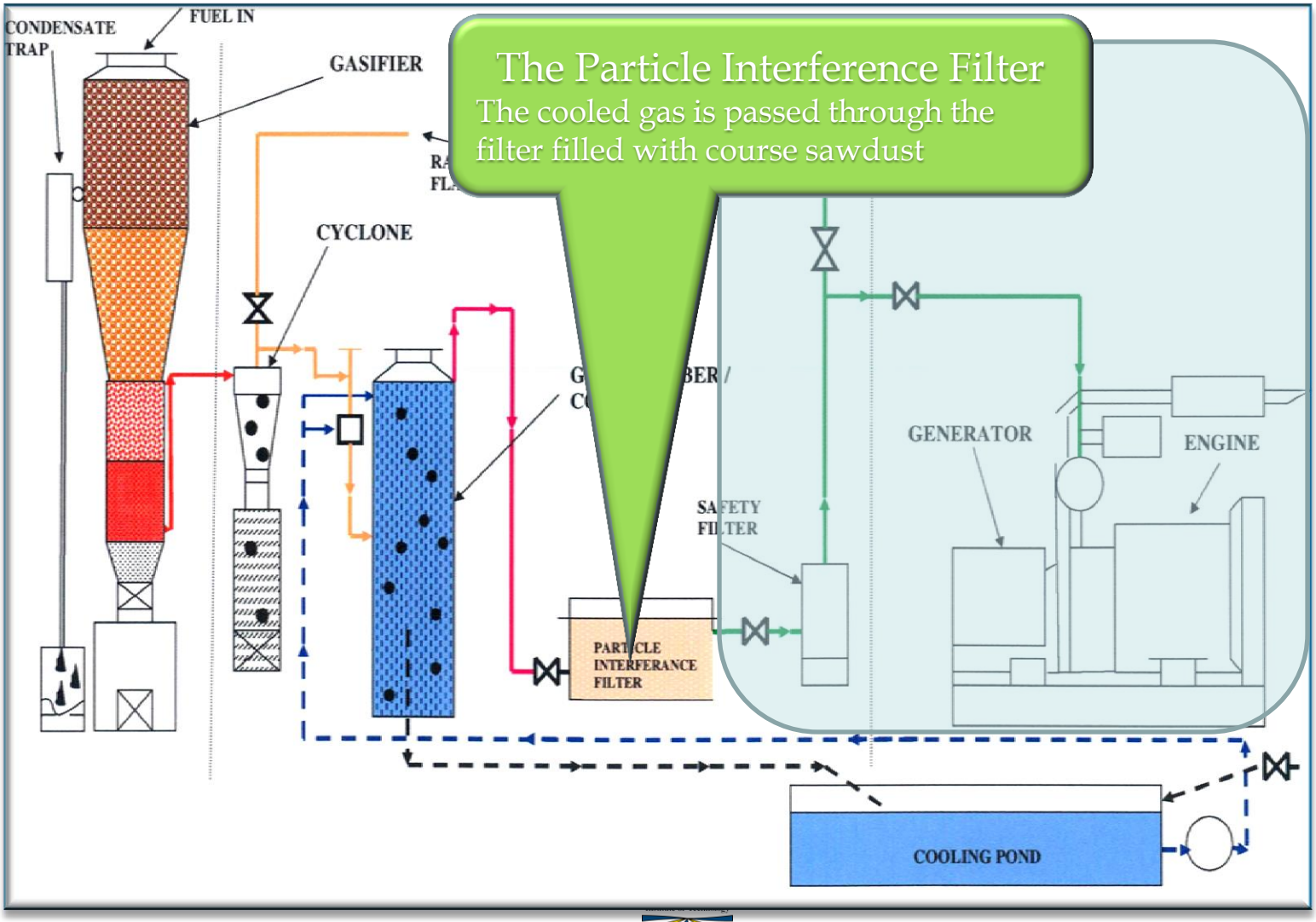


The Gas Scrubber / Cooler.

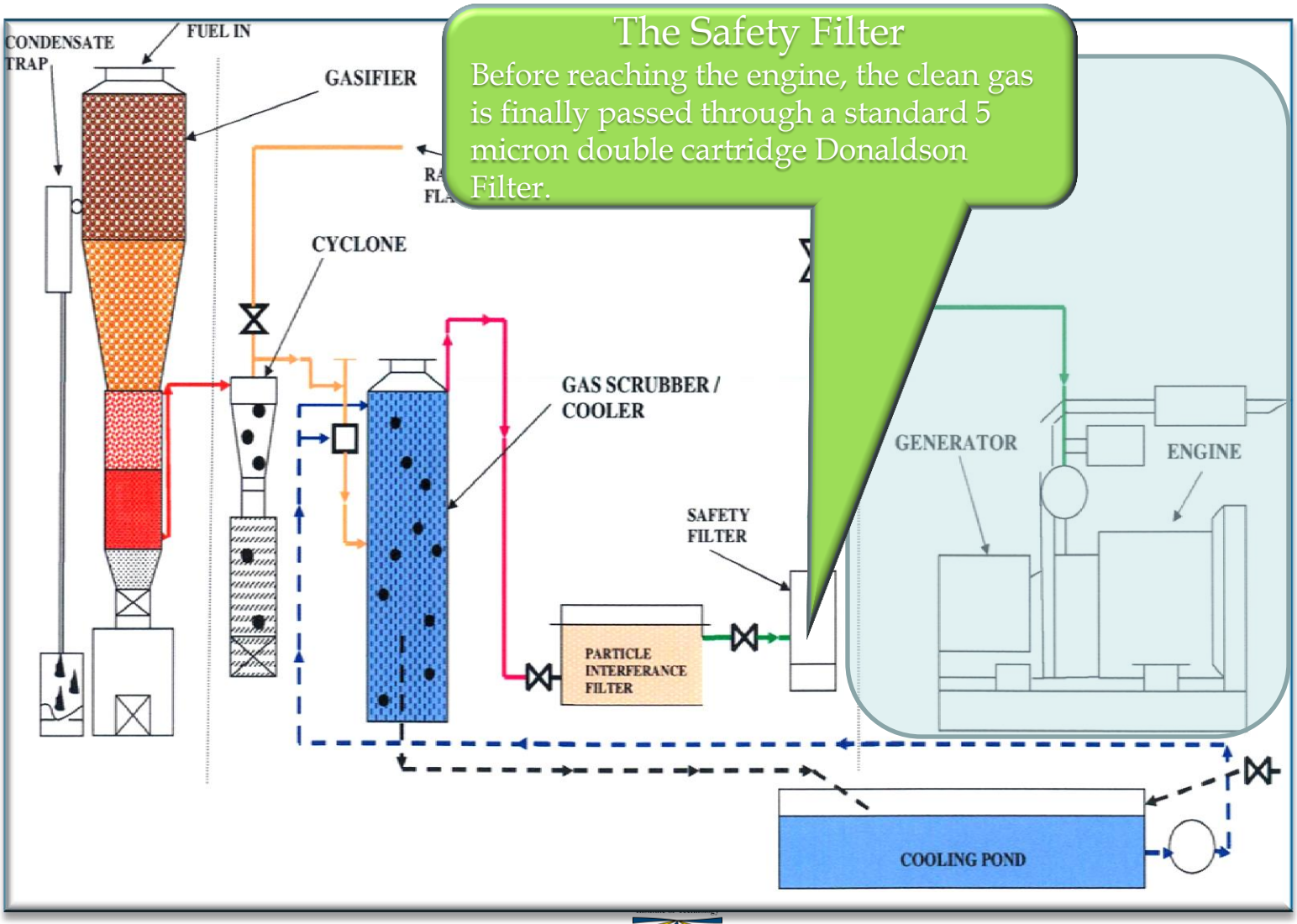
After the course dust has been removed from the cyclone, the fine dust(5ml/N^3) is carried with the sprayed scrubbing water over a low resistance porous scrubbing media. The water is recycled through an ambient cooling pond. The gas is cooled to ambient temp.



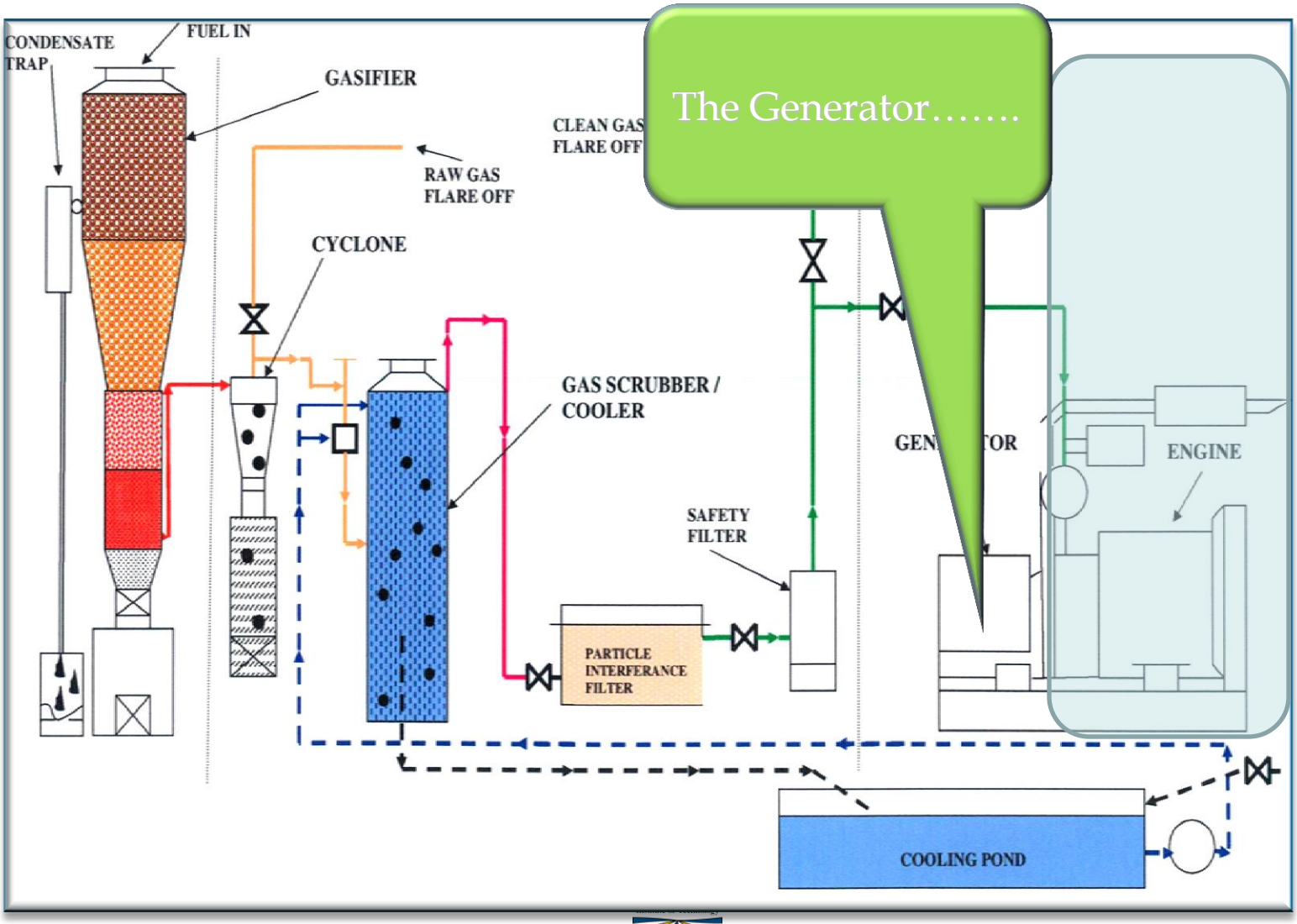
The long life particle interference filter….



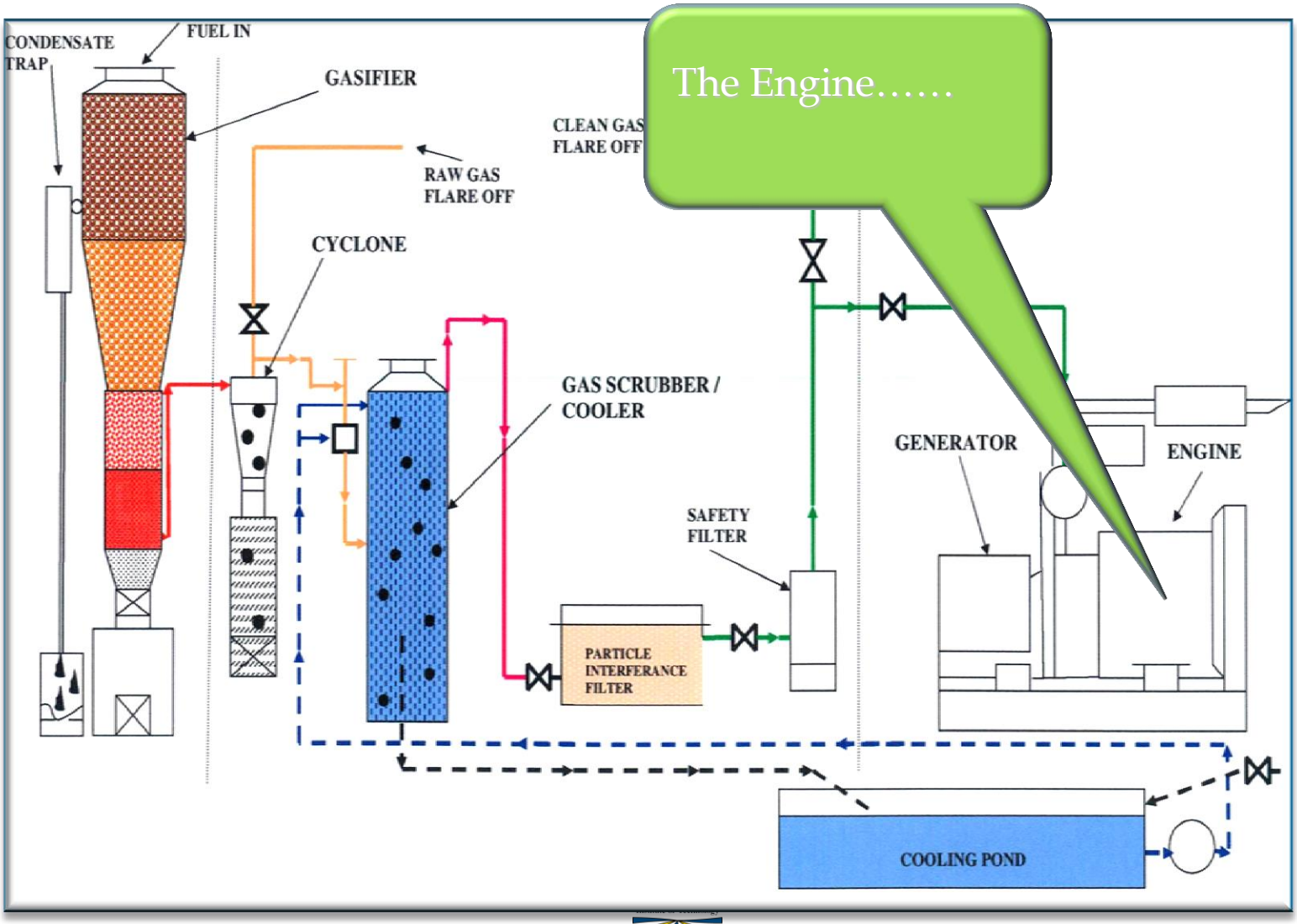
The safety filter….



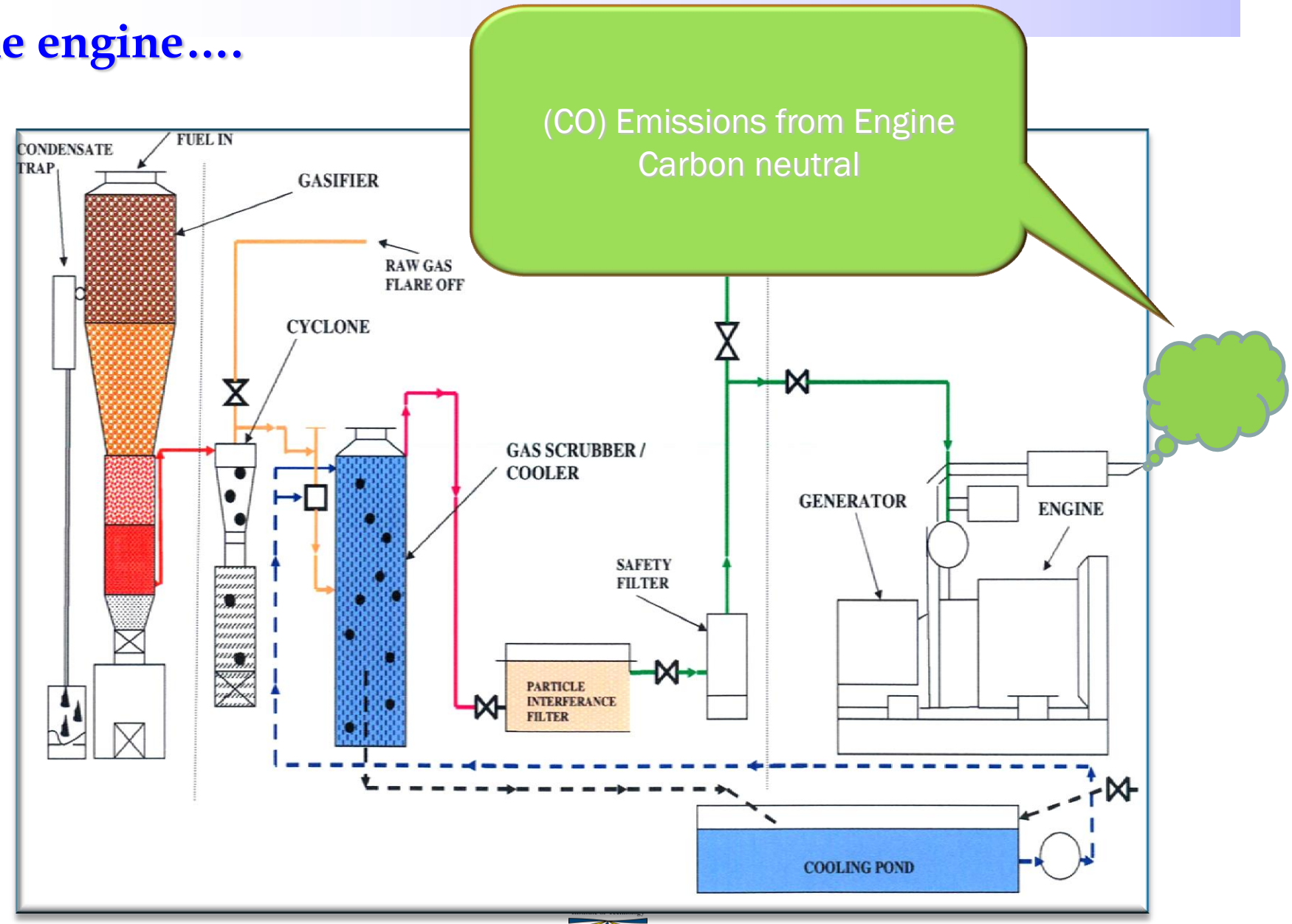
The generator….



The engine….

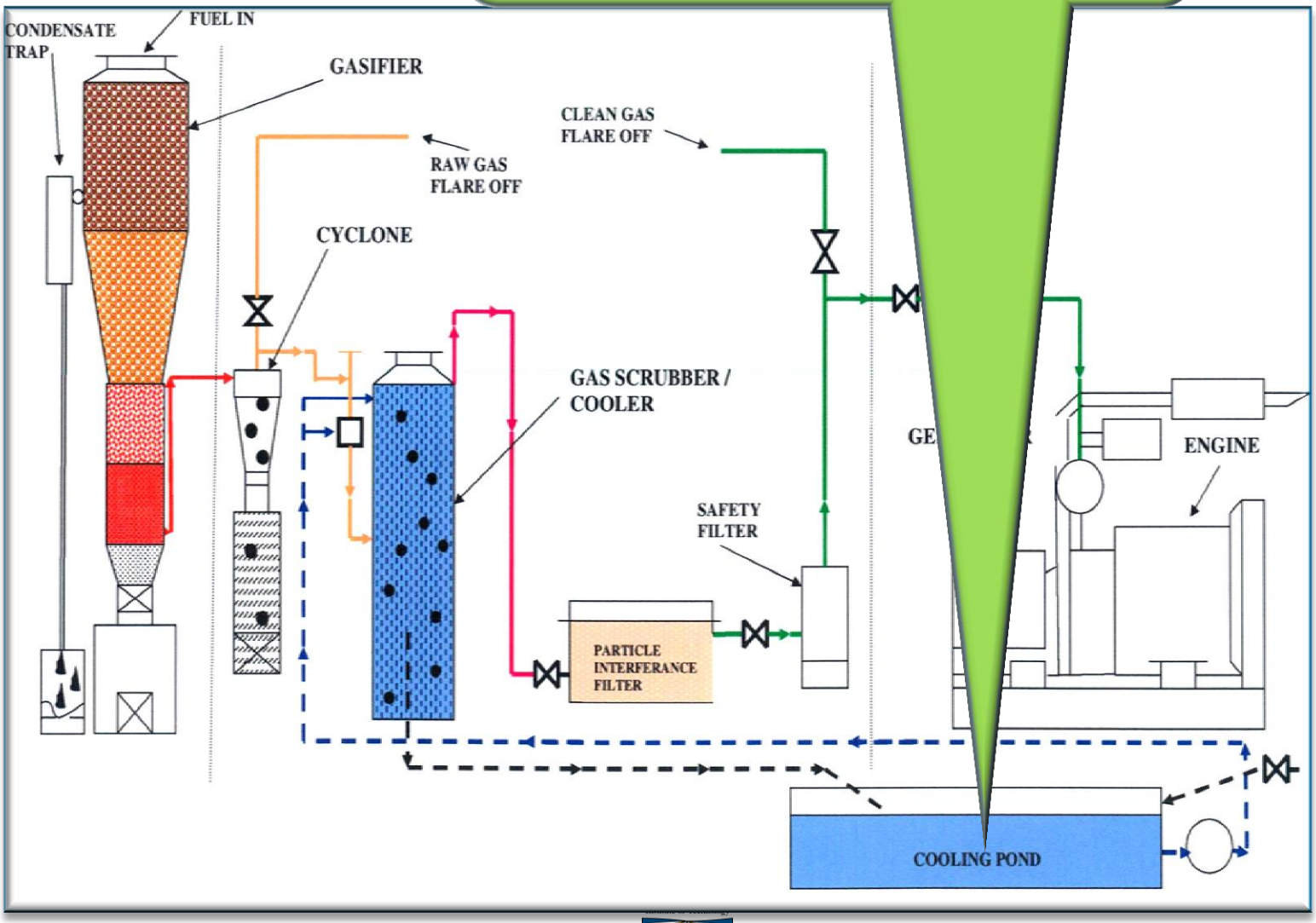

CONDENSATE TRAP
FUEL IN
GASIFIER
CLEAN GAS FLARE OFF
RAW GAS FLARE OFF
CYCLONE
GAS SCRUBBER / COOLER
SAFETY FILTER
PARTICLE INTERFERANCE FILTER
GENERATOR
ENGINE
COOLING POND
The Engine……

The engine….


(CO) Emissions from Engine
Carbon neutral
CONDENSATE TRAP
FUEL IN
GASIFIER
RAW GAS FLARE OFF
CYCLONE
GAS SCRUBBER / COOLER
SAFETY FILTER
PARTICLE INTERFERANCE FILTER
GENERATOR
ENGINE
COOLING POND

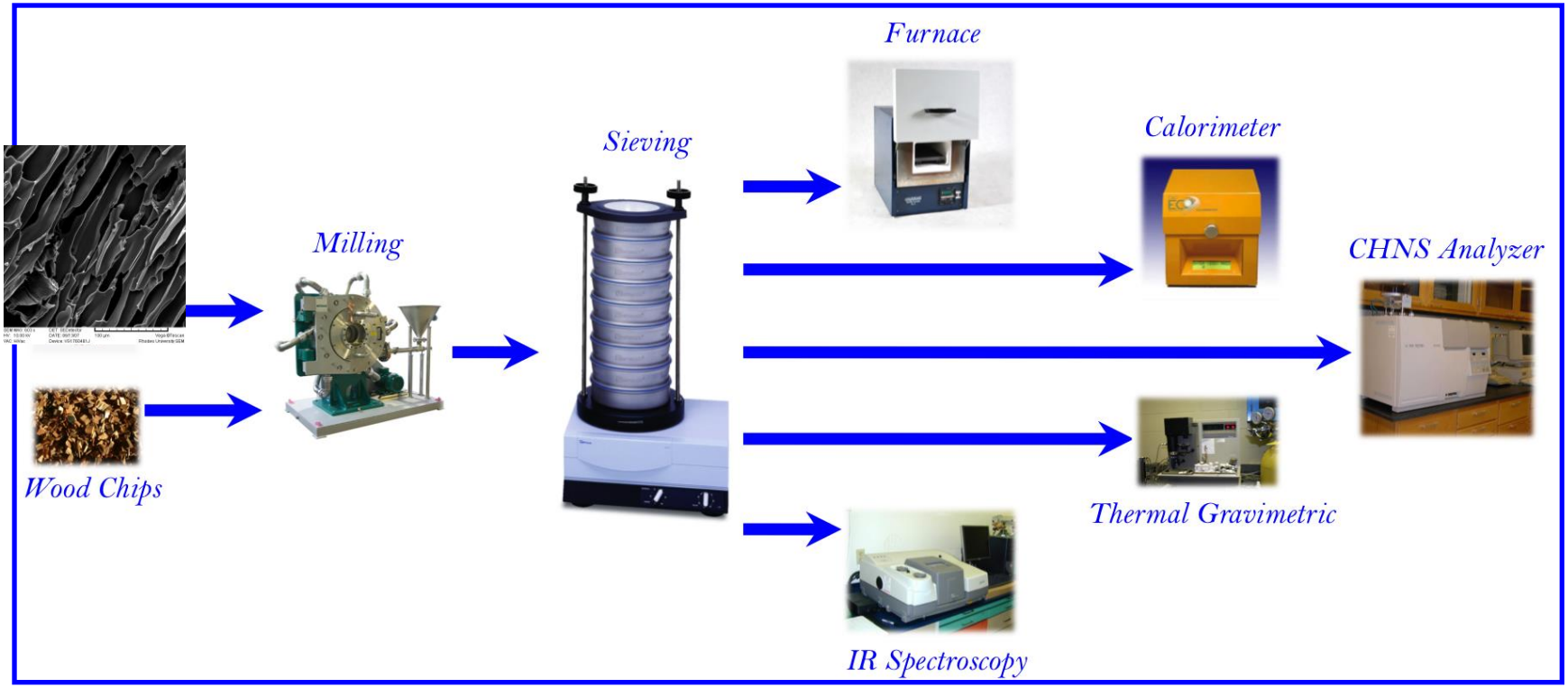
The cooling pond….

The Cooling Pond……
Water contains no toxic elements and can be used for irrigation purposes!



Prototype for R&D

BIOMASS CHARACTERIZATION



- 150 kVA Melani village gasifier



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The gasifier

Presented by: Sampson Mamphweli

Thank you