Introduction to AD Engineering Part 2

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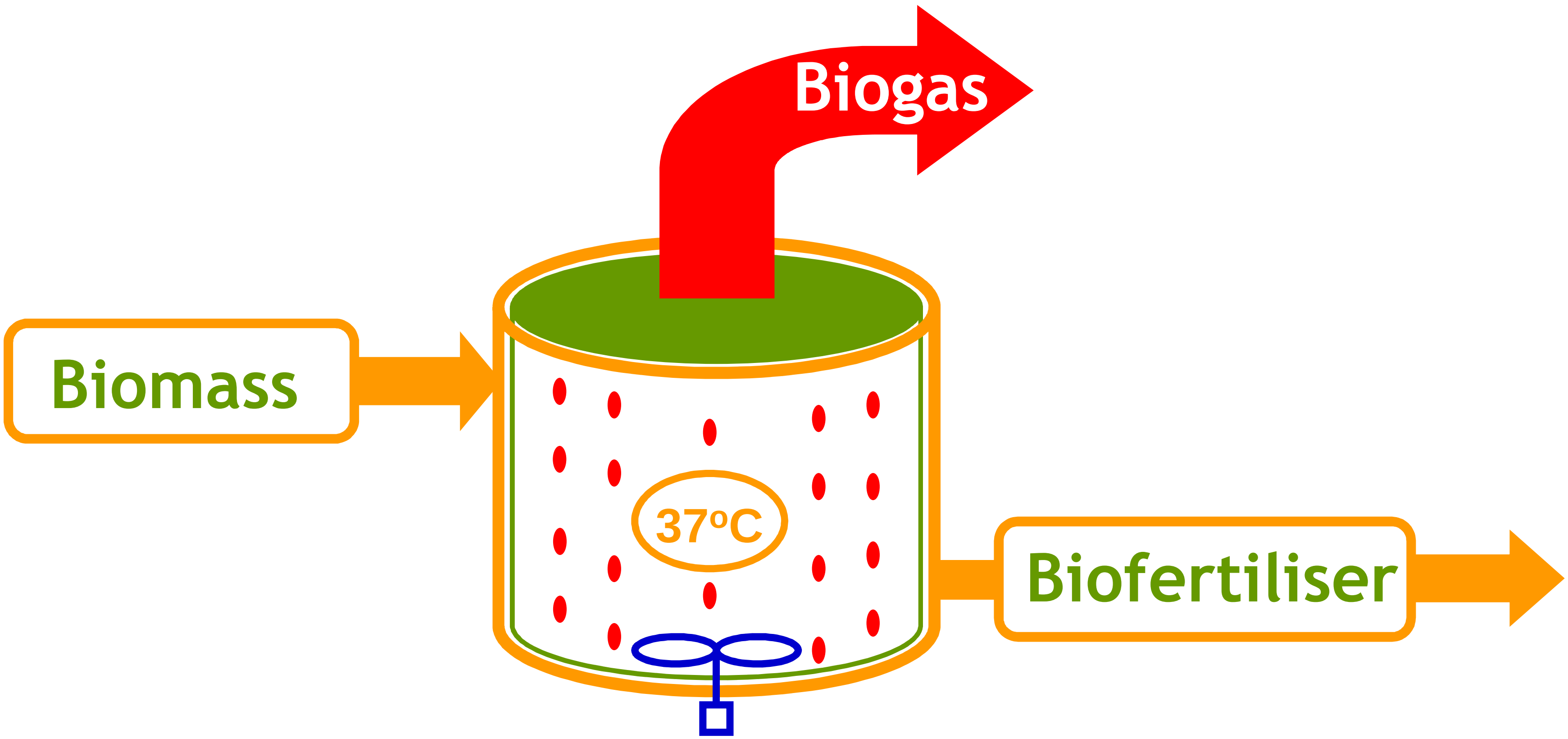
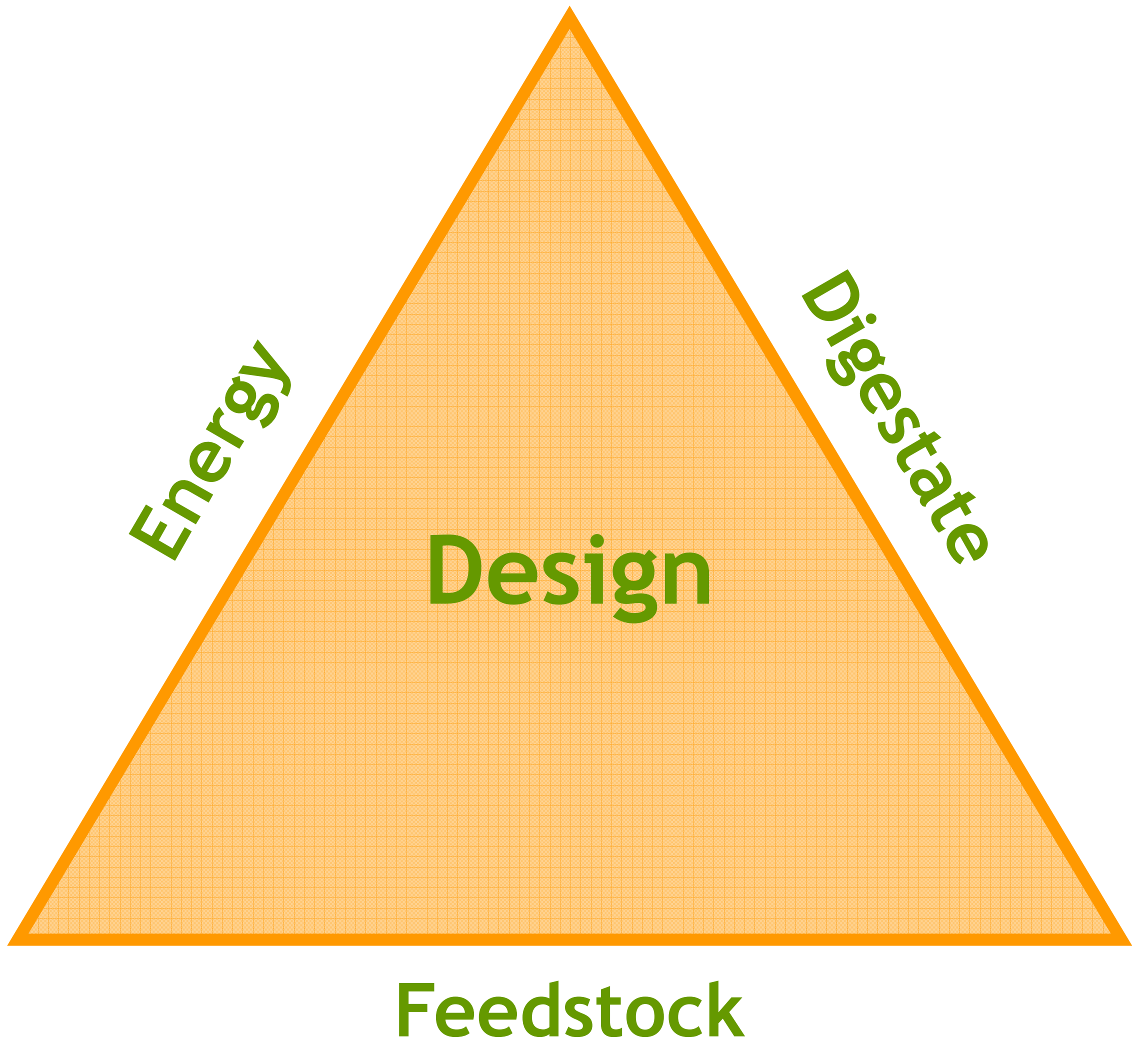
Anaerobic Digestion
a Natural Biological Process



AD Engineering

- Engineering design
- Process calculations
- Energy balance
- Mass balance


Energy
Digestate
Design
Feedstock

Process Calculations

- Feedstock Parameters
- Digester Sizing
- Energy Balance
- Mass Balance

Key Feedstock Parameters

- Mass – $tonne.d^{-1}$
- Dry Matter - %DM
- Organic Dry Matter - %ODM
- BMP – $m^3_{CH4}.tonne_{ODM}^{-1}$
- CH_4 - %

% Dry Matter

The figure for %DM is measured as follows:

A measured amount of biomass is weighed (x gms).

The biomass heated to a temperature of 105^{o}C until all the moisture is driven off.

The dry biomass is weighed (y gms).

%DM = y/x*100

% Organic Dry Matter

The figure for %ODM is measured as follows:

Dry biomass from the %DM test is weighed (y gms).

The dry biomass is heated in an oven to a temperature of 550°C and maintained at this temperature for a period of two hours.

The oven drives off all the volatile material leaving the inert fraction, which is weighed (z gms).

%Inert = z/y*100 (expressed as % of dry matter).

%ODM = 100-%Inert =100-(z/y*100).

Biochemical Methane Potential

BMP is expressed as m^3 CH_4 per tonne ODM.

The figure for BMP is obtained empirically by experiment, either in laboratory digesters or in full-scale digesters.

The BMP varies from as low as $190m^3_{CH4}.tonne^{-1}_{ODM}$ for the anaerobic digestion of cattle manure (the cow is a very good digester) to as high as 450 for some food waste and energy crops.

It should be noted that the use of %DM, %ODM and BMP is a convention for the anaerobic digestion of biomass; it is not scientifically exact.

% Methane of Biogas

The % methane of the biogas is important for two reasons: first, the design of the gas utilisation system; and second, the mass balance.

It is assumed that the balance of the biogas is CO_2.

CH_4 has a density of 0.71kg.m^{-3}. (This is on the basis that 1 kmol of a perfect gas occupies 22.4m^3).

CO_2 has a density of 1.96kg.m^{-3}.

The density of biogas is approximately:-

$\%CH_4/100*0.71+(100-\%CH_4)/100*1.96$.

Biogas @60% CH_4 has a density of about 1.21kg.m^{-3}.

Anaerobic Digestion Parameters

For this lecture the only type of anaerobic digestion being considered is the Continuous Stirred Tank Reactor ("CSTR"). This is one which is fed semi-continuously (at least once per day) and is fully mixed.

The following are parameters measured in the anaerobic digestion stage:

- Hydraulic Retention Time (HRT)

- Organic Loading Rate (OLR)

Hydraulic Retention Time (HRT)

The Hydraulic Retention Time (days) is defined as the volume of the digester (m^3) divided by the daily feed rate (m^3/day).

The retention time is not the same as the length of time the biomass is in the digester, unless there is a perfect plug flow.

The parameter is useful when considering feedstocks with %DM between about 4% and 12%, e.g. for animal slurry, in which case the optimum retention time will be between 10 and 25 days.

For higher levels of %DM the parameter is less important since it is not the rate-limiting one.

Organic Loading Rate (OLR)

The Organic Loading Rate ($kg_{ODM}.m_R^{-3}.d^{-1}$) is defined as the mass of organic matter (kg) fed to the digester in one day divided by the volume of the digester (m^3).

The OLR tends to be the rate-limiting parameter when the %DM of the feedstock is more than about 12%; below this the HRT is the rate-limiting parameter.

A well-designed anaerobic digester will maximise the organic loading rate, and this will vary according to the feedstock and according to the digester design.

A typical figure is between 3 & 6 kg ODM/m^3/day.

Process Calculations

Mass & Energy Balance (Scenario C)