

Review of biogas production processes - examples of ongoing projects

Charles Banks
University of Southampton, UK

Renewable Bioenergy Alternatives for City
Transport Applications
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**BIODEGRADABLE ORGANIC MATERIAL
(CARBOHYDRATES, FATS, PROTEINS)**

HYDROLYSIS

SIMPLE SOLUBLE ORGANICS

ACID FERMENTATION

ACETIC ACID

**PROPIONIC ACID
BUTYRIC ACID
LONG CHAIN VFA**

ACETOGENESIS

ACETIC ACID

H₂ + CO₂

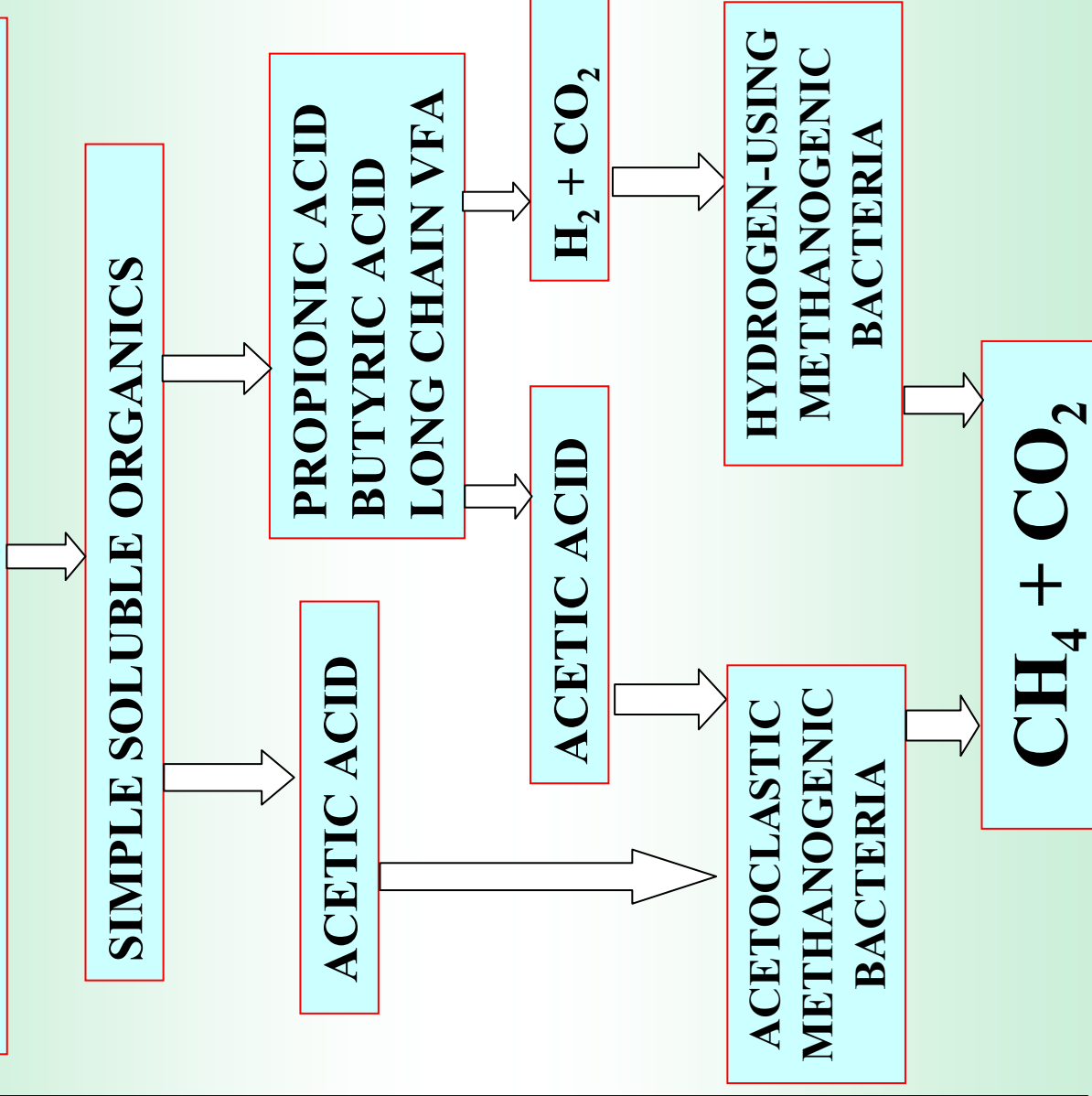
METHANOGENESIS

**ACETOCLASTIC
METHANOGENIC
BACTERIA**

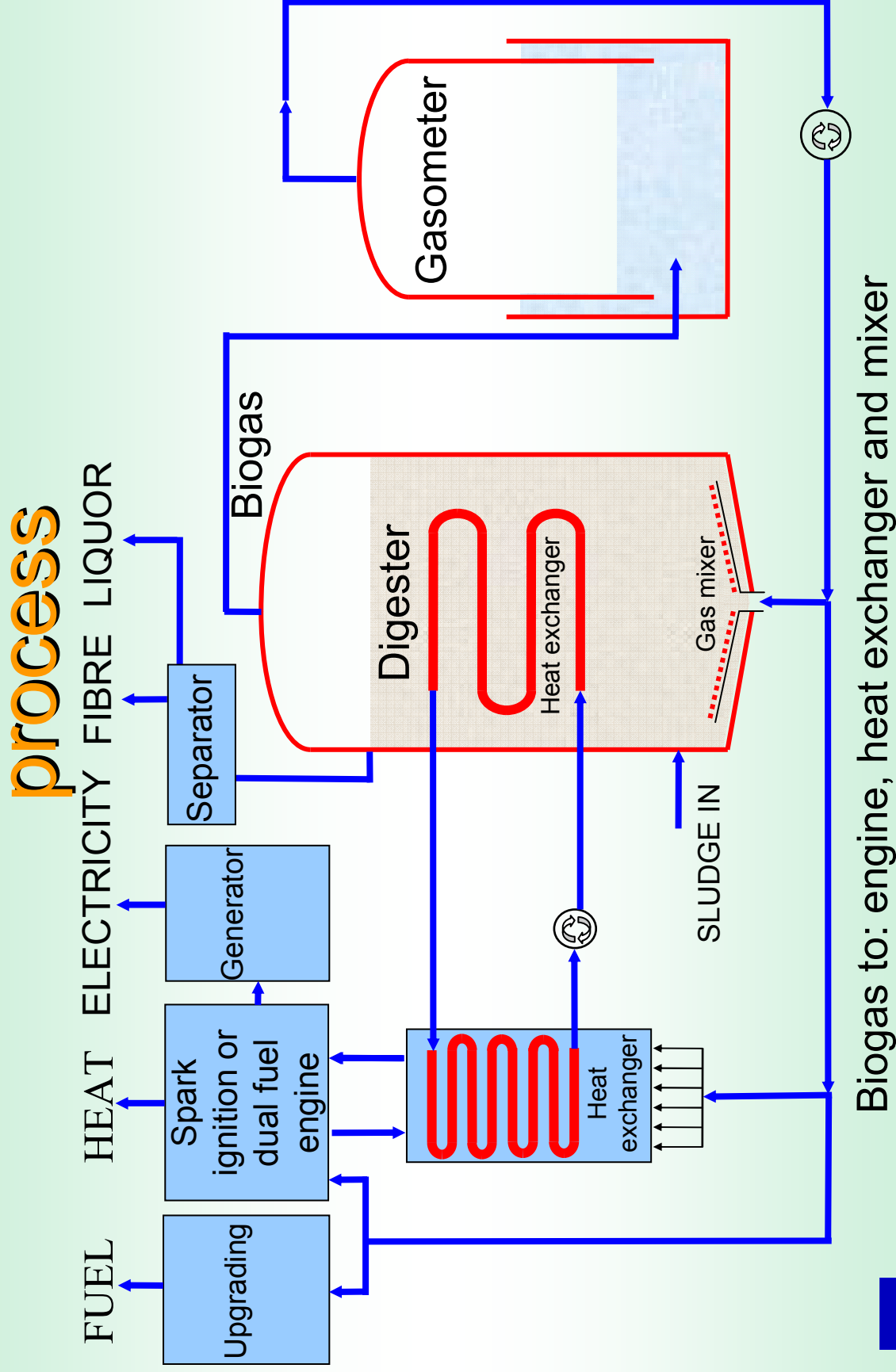
**HYDROGEN-USING
METHANOGENIC
BACTERIA**



CH₄ + CO₂



Components of a controlled AD process



Old technology - new applications

- The technology is well established
- Traditionally it has been used for waste stabilisation
- Currently the focus is on energy production
- To be cost-effective in this role may require
 - engineering and technical improvements and operational approaches to increase conversion efficiencies
 - Selection and/or the production of biomass feedstocks from a variety of sources
 - including novel and multi-use crops and agro-wastes from integrated farming systems, commercial and industrial wastes and by-products.



Process types

Wet

Dry

Mesophilic

Thermophilic

One stage

Multi-stage



Instant recognition!



Biomass resources suitable for anaerobic digestion

- Animal slurries
- Agricultural residues
- Energy crops
- Sewage sludge
- Biodegradable municipal solid waste
- Biodegradable commercial and industrial waste



Potential Industrial co-digestates

- Leather production and processing
 - tissue and collagen fleshings
- Pulp and paper industry wastes
- Pharmaceutical waste
- Brewing and distillery waste
- Biofuel production
 - glycerol and pressed oil cakes
- Starch production
 - potato, maize, rice residues and sludge



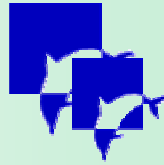
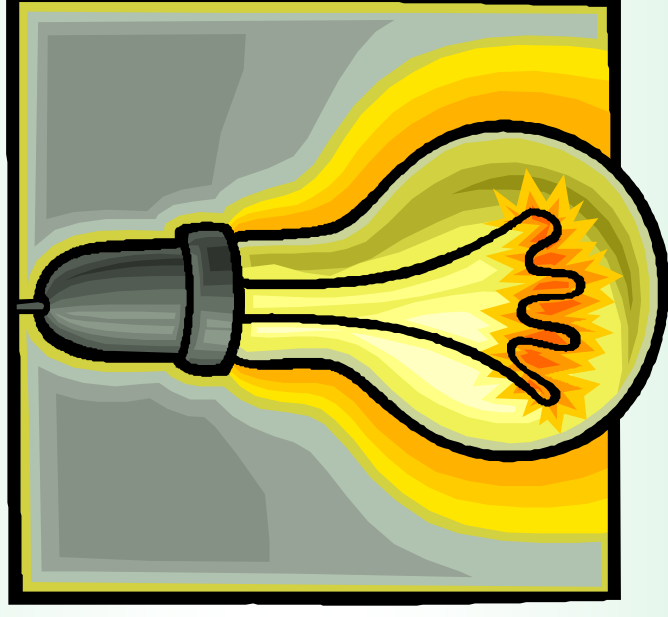
Biogas yields (m^3 wet tonne^{-1})

Manure & slurry	Biogas yield	Industrial & commercial waste residues	Biogas yield	Agricultural energy crops	Biogas yield
Dairy cattle	20	Potato distillery	35	Meadow grass	98
Fattening cattle	34	Vegetable processing	35	Maize silage	190
Pig	18	Rape seed cake	612	Grass silage	183
Poultry	93	Canteen waste (high fat)	90	Milled grain	597
		Canteen waste (low fat)	44	Corn cop mix (5.3% fibre)	391
		Flotation fat	108	Total plant grain silage	195



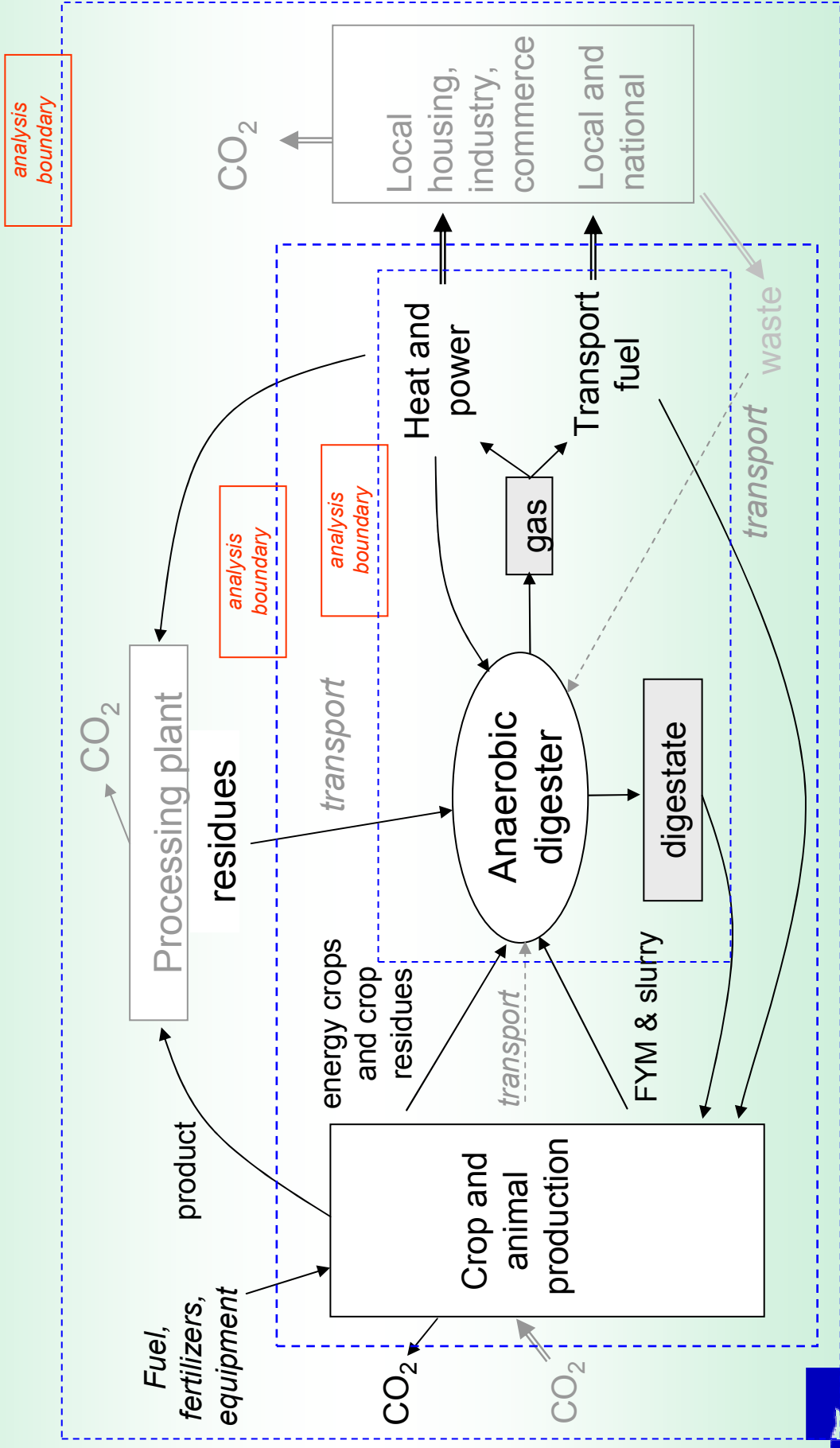
How much energy can we get?

- Biogas has a methane content of $\approx 60\%$ with a thermal value 36 MJ m^{-3}



Biogas as a renewable energy source

source



Anaerobic digestion and farming



Benefits in using anaerobic digestion in agriculture

- Provides a source of renewable energy
- Improves nutrient management and soil structure
- Can help to abate greenhouse gas emissions



Finland: small-scale integrated farming system



Kalmari Farm





Austrian farm-based AD plant



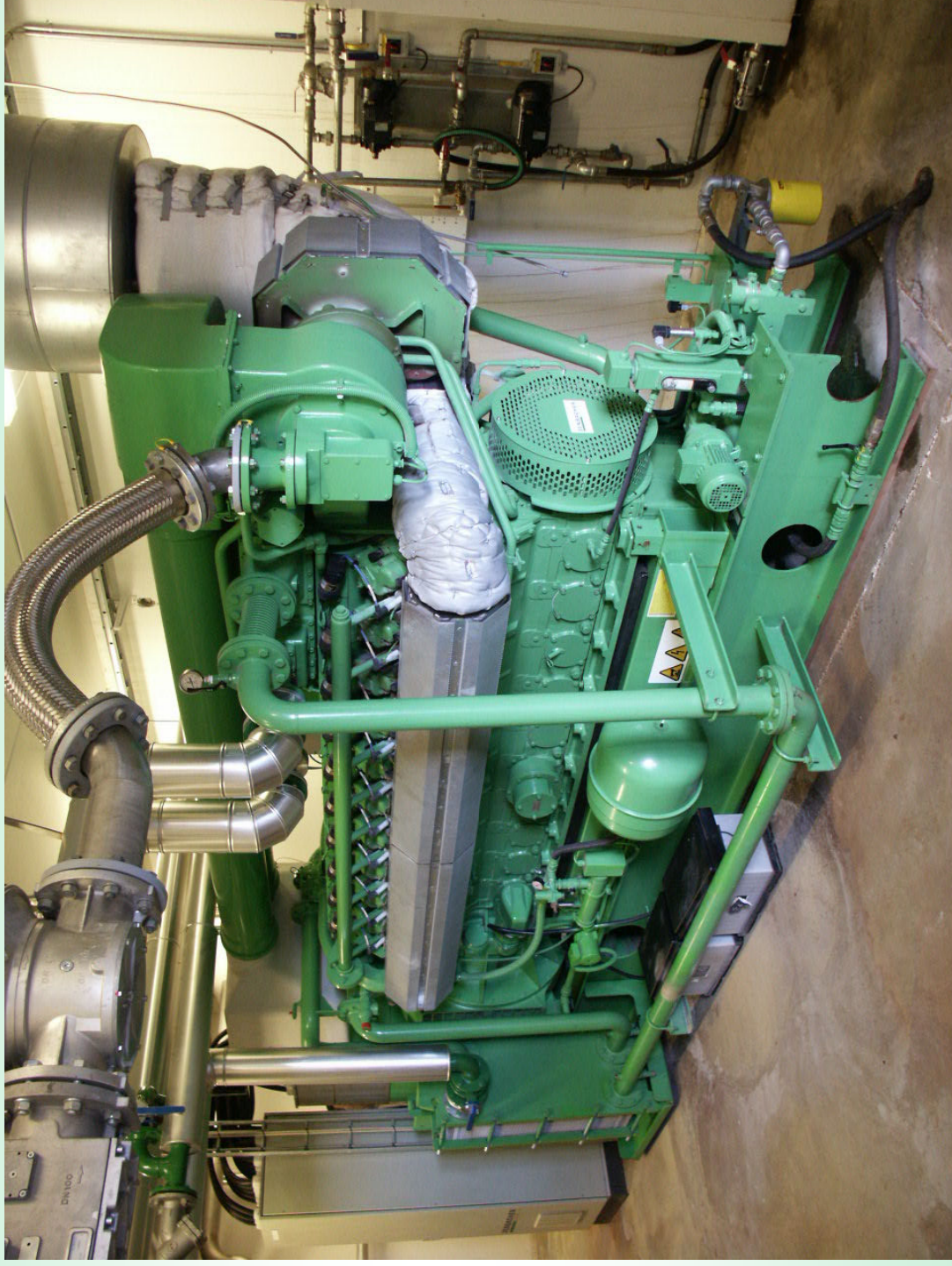
Maize silage and agro wastes



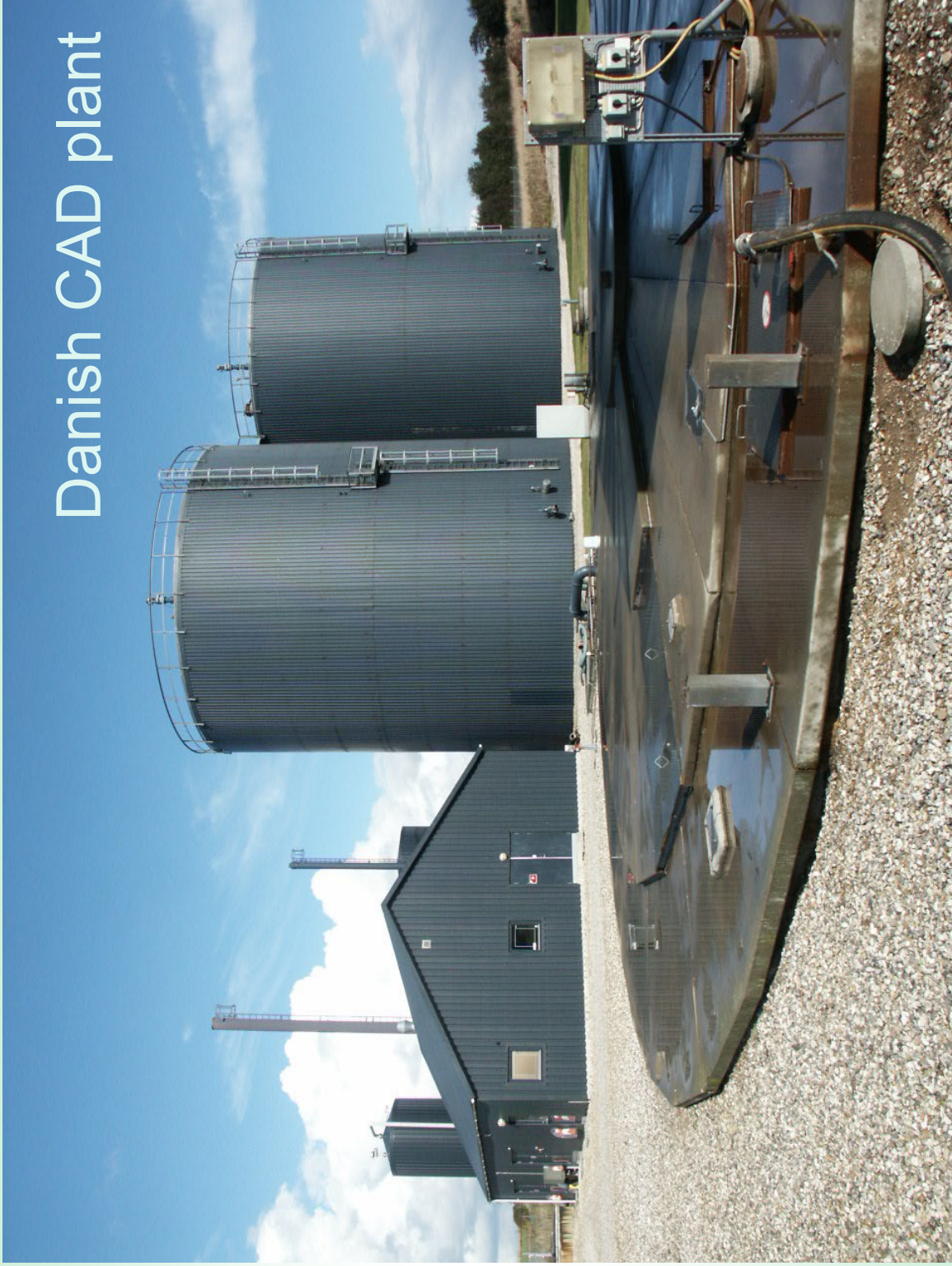
Digestion plant



Electricity generation



Danish CAD plant



Manure management, power generation & district central heating



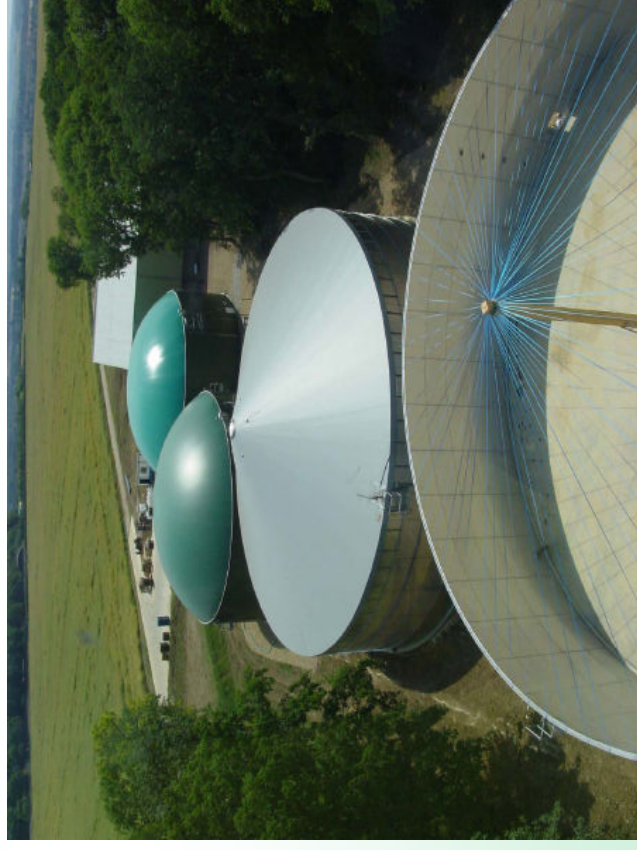
Västerås biogas plant (AGROPTI-gas)



Biogas – fuel for public service vehicles



Centralised anaerobic digestion plant - UK



**All of the above have used wet
single phase mesophilic digesters**



Indonesia



USA



Municipal solid waste

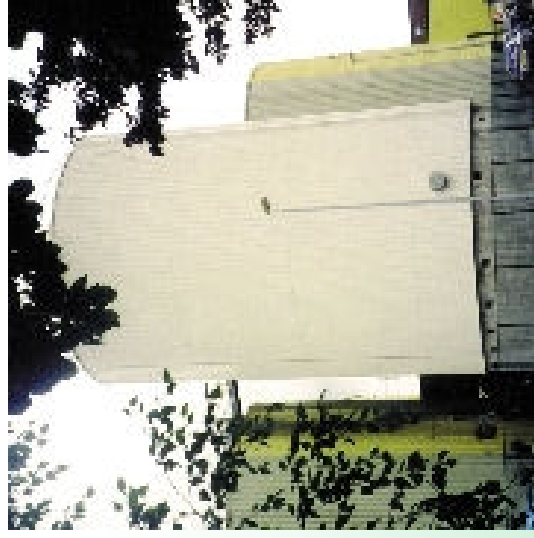


MSW that can be digested

- Mixed household waste after pre-processing
- Source-segregated organic fraction of household waste
- Garden waste
- Market wastes
- Waste from certain municipally located industries eg. food processors and packagers



A selection of MSW digesters



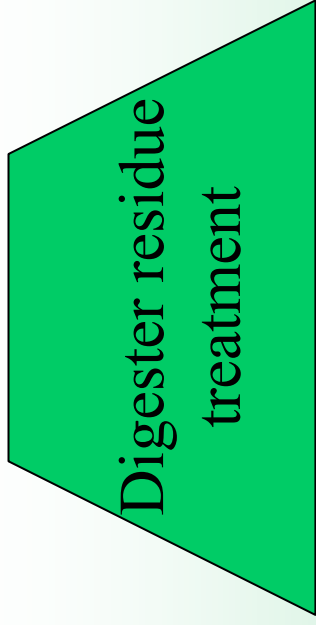
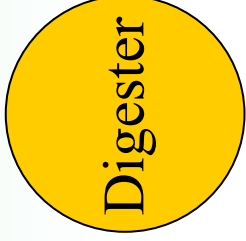
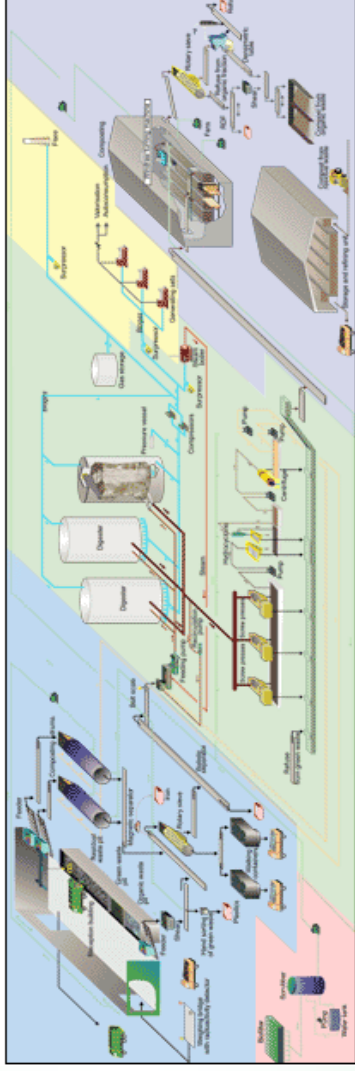
Facts and figures (Luc De Beer,)

- Over 50 operational plants in Europe treating either MSW or market wastes
- Total annual throughput in excess of 1 million tonnes
- Increase of over 750% in a decade
- Average size of new projects greater than 50,000 tonnes/year
- Some plants now treating 100,000 tonnes per annum
- More than 150 plants worldwide, treating 5 million tonnes of waste and generating over 600MW of electricity



Residual waste treatment

The digester must be part of an integrated package



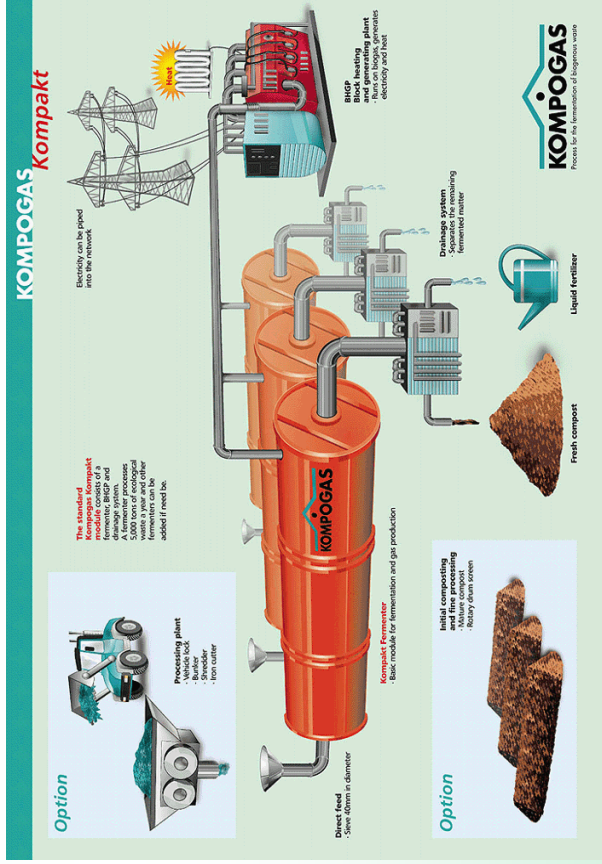
Source segregated waste treatment

Green waste
Market waste
Kitchen waste

Digester

Final product

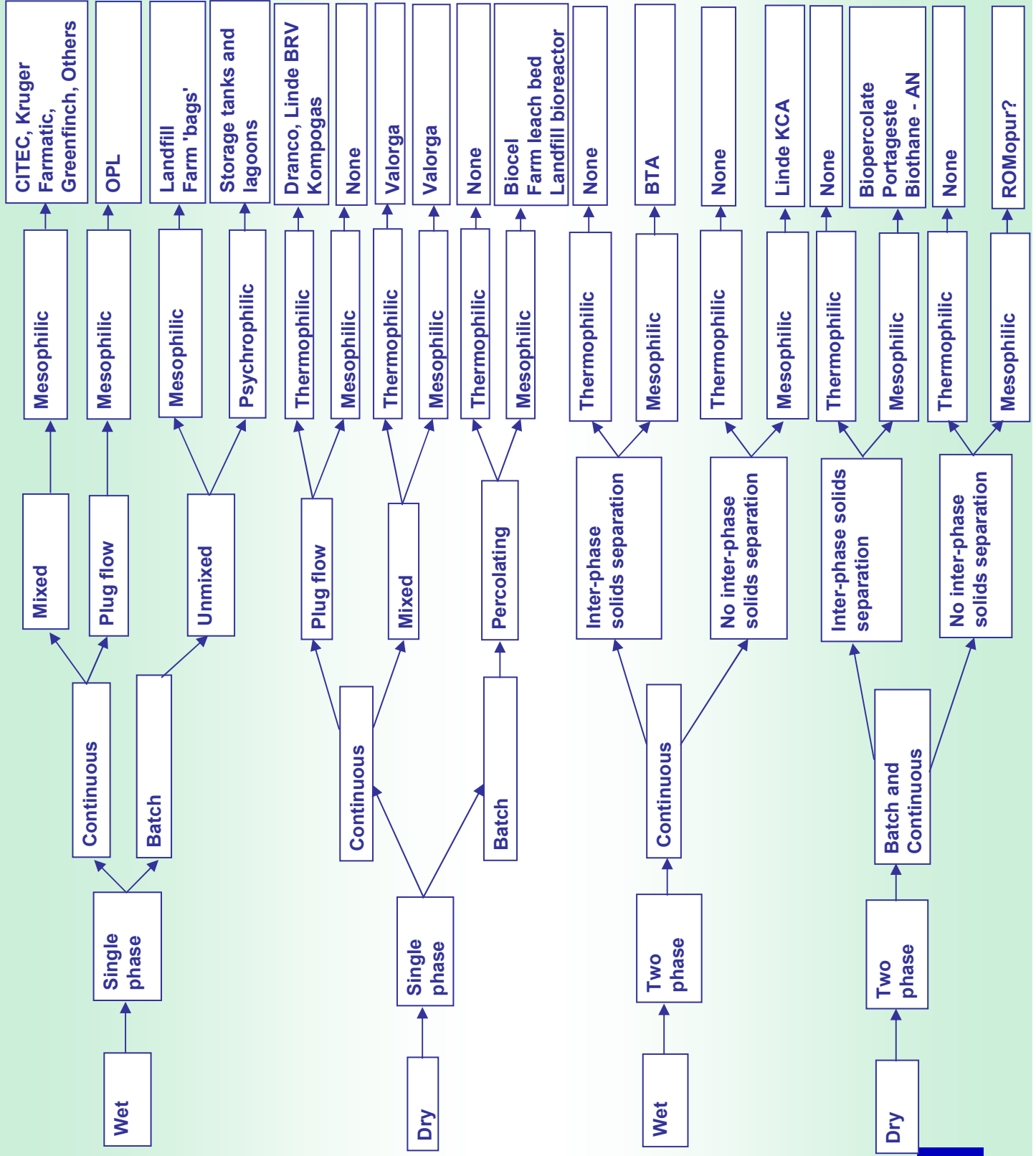
The pre-treatment and post treatment are minimised



Important factors in decision making

- Choice of feedstock = quality of product
- Energy balance
- Fertiliser value and markets for digestate
- Odour generation and gas cleaning
- Downstream processing, storage, and maturation of digestate
- Hygiene
- Proximity principal





Thank you

- Thanks also to those that support our research:
 - RELU- rural economy and land use programme ESRC (UK)
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 - European Union

