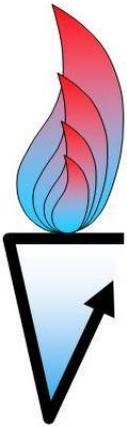




Università
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Dipartimento
di Scienze Ambientali
Informatica e Statistica



AD OF FOOD WASTE: MATCHING PROCESS DESIGN TO FEEDTOCK CHARACTERISTICS

Dr. CRISTINA CAVINATO
LECTURE 2



JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

*Summer School on Biogas Technology for sustainable
Second Generation Biofuel Production, 15-19 August 2011*

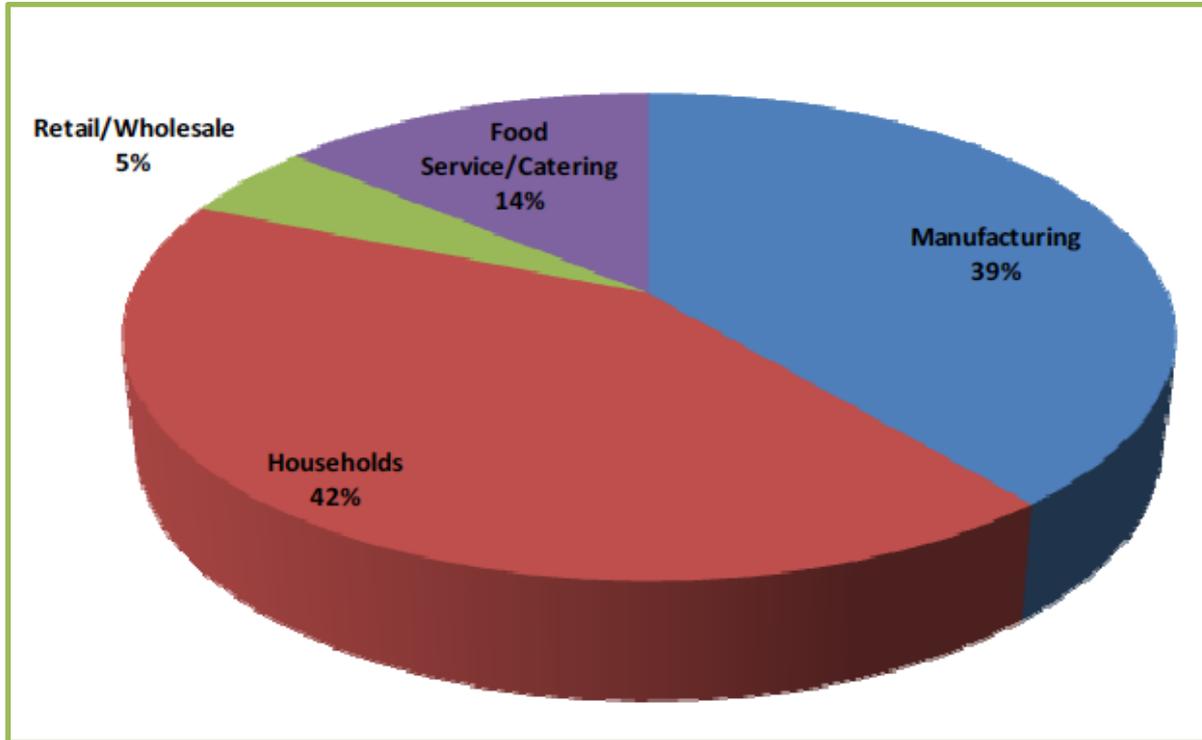
DEFINITIONS

Bio-waste is defined by the European Commission in the green paper on the management of bio-waste as *biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants*. The definition does not include forestry or agricultural residues, manure, sewage sludge or other biodegradable waste, such as natural textiles, paper or processed wood.

Bio-waste accounts for 30-45 % of municipal solid waste in Europe.

Food waste, composing a large proportion of bio-waste, is waste composed of raw or cooked food materials and includes food materials discarded at anytime between farm and fork; in households relating to food waste generated before, during or after food preparation, such as vegetable peelings, meat trimmings, and spoiled or excess ingredients or prepared food.

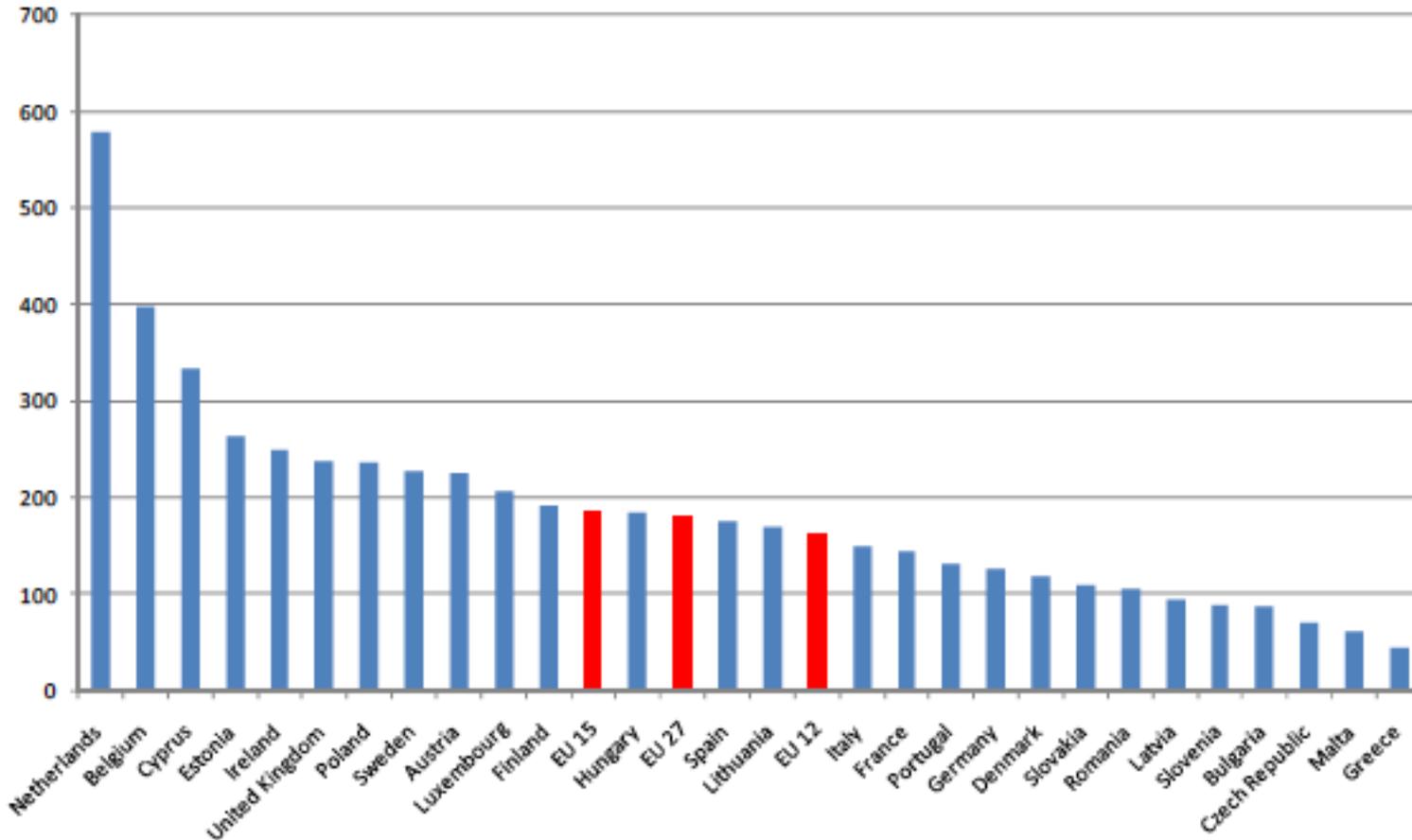
Around 90 million tonnes of food waste are generated in the EU each year or 179kg per capita (EUROSTAT 2006)



Households produce the largest fraction of EU food waste among the four sectors considered, at about 42% of the total or about 38Mt, an average of about 76kg per capita.

Food which ends up as being discarded by households represents 25% of food purchased (by weight), according to studies completed by WRAP 2009 (Waste & Resources Action Programme). For the UK, the avoidable portion of this food waste represents a total annual loss per household of approximately 565Euros.

Total food waste arisings by MS based on best available data (kg per capita per year)



(october 2010-European Commission [DG ENV - Directorate C]
Final Report – Preparatory Study on Food Waste)



EU POLICY MEASURES TO REDUCE FOOD WASTE

Biodegradable waste diversion targets of the Landfill Directive 1999/31/EC

The Council Directive 1999/31/EC of 26 April 1999 also known as the Landfill Directive, sets as a policy target the staggered reduction of biodegradable municipal waste (BMW) going to landfill. The Landfill Directive places an absolute target on the tonnage of BMW that can be land filled by 2006, 2009 and 2016 by linking the quantity permitted to the quantity produced in 1995. Thus the Directive obliges MS to reduce the amount of biodegradable waste in landfills by 65% by 2016 compared to 1995 levels. This means, for instance, that if BMW production doubles between 1995 and 2016, only 17.5 % of BMW produced in 2016 can be land filled. As of 2006, MS are restricted to land filling a maximum of 75% of the total amount by weight of BMW produced in 1995. This target becomes 50% in 2009 and 35% in 2016. **However, the Landfill Directive does not submit countries to binding specifications on methods for disposal of BMW not sent to landfills, a situation which has led most MS to opt for incineration.**

*(October 2010-European Commission [DG ENV - Directorate C]
Final Report – Preparatory Study on Food Waste)*



EU POLICY MEASURES TO REDUCE FOOD WASTE

Waste Framework Directive

Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 aims to protect human health and the environment against harmful effects caused by the collection, transportation, treatment, storage and disposal of waste.

On June 17th 2008, the European Parliament adopted a legislative resolution approving the Council's common position for **a new Waste Framework Directive**. The Waste Final Report Framework Directive was reviewed with the aim of simplifying it, providing clearer definitions and strengthening the measures required on waste prevention.

The revised Directive will streamline EU waste legislation by replacing three existing directives: the current Waste Framework Directive, the Hazardous Waste Directive and the Waste Oils Directive.

*(october 2010-European Commission [DG ENV - Directorate C]
Final Report – Preparatory Study on Food Waste)*



EU POLICY MEASURES TO REDUCE FOOD WASTE

The revised Directive:

- sets new recycling targets to be achieved by MS by 2020
- strengthens provisions on waste prevention through an obligation for MS to develop national waste prevention programs and a commitment from the EC to report on prevention and set waste prevention objectives
- sets a clear, five-step hierarchy of waste management options in which prevention is the preferred option, followed by re-use, recycling and recovery, with safe disposal as the last recourse
- clarifies a number of important definitions, such as recycling, recovery and waste, also draws a line between waste and by-products and defines end-of waste criteria

*(october 2010-European Commission [DG ENV - Directorate C]
Final Report – Preparatory Study on Food Waste)*

EU POLICY MEASURES TO REDUCE FOOD WASTE

Furthermore, there is a clear strategy towards the separate collection and treatment of bio-waste:

Article 22 “Bio-waste”: “Member States shall take measures, as appropriate, and in accordance with Articles 4 and 13, to encourage:

- (a) the separate collection of bio-waste with a view to the composting and digestion of bio-waste
- (b) the treatment of bio-waste in a way that fulfils a high level of environmental Protection
- c) the use of environmentally safe materials produced from bio-waste

*(october 2010-European Commission [DG ENV - Directorate C]
Final Report – Preparatory Study on Food Waste)*

EU POLICY MEASURES TO REDUCE FOOD WASTE

Green Paper on bio-waste management in the EU

In December 2008, the Commission published a Green Paper on bio-waste management in the EU and launched a consultation process to gather opinions on whether a specific stand-alone EU Bio-waste Directive was needed.

The purpose of the Green Paper was to explore options for the further development of the management of bio-waste by reviewing the current situation of bio-waste management in the EU.

*(October 2010-European Commission [DG ENV - Directorate C]
Final Report – Preparatory Study on Food Waste)*

EU POLICY MEASURES TO REDUCE FOOD WASTE

Communication on future steps in bio-waste management in the European Union

In May 2010, the Commission released a Communication on bio-waste management in the EU, including recommendations on managing bio-waste such as [encouraging the usage of separate collection](#) as well as laying out the future planned steps on the part of the EC for addressing bio-waste in the EU.

The key tenets of EC future action related to bio-waste include:

- encouragement of prevention of bio-waste, treatment of bio-waste according to the waste hierarchy,
- protection of EU soils via a focus on compost and digestate,
- investment in research and innovation and efforts to reinforce the full implementation of the existing set of EU waste legislation.

*(october 2010-European Commission [DG ENV - Directorate C]
Final Report – Preparatory Study on Food Waste)*



BIOLOGICAL TREATMENT OF FOOD WASTE



ANAEROBIC DIGESTION OF OFMSW

Organic

Fraction

Municipal

Solid

Waste

How to obtain a good quality OFMSW?
The importance of separate collection





Door to door
collection



Residential area
collection



Street collection



- MS-OFMSW: mechanically selected
- SS-OFMSW: source sorted
- SC-OFMSW: separate collection

Collection strategy



Quality of waste obtained



Biogas yields

Unsorted wastes:

- separation and partial material recovery (inerts, metals, low quality organic fraction);
- reduction of waste amount to be sent to landfill;
- best combustion quality (less moisture and inerts, improved heating value).

Sorted wastes:

- organic waste selection before treatment (plastics, inert, metals)

AIM

Substrate pre-treatment has the aim of:

- Receiving the waste and stock it while awaiting for treatment;
- Removing not degradable fractions (e.g. ferric and inert materials, plastic, etc.);
- Homogenizing the substrate;
- Making particles size compatible with the process and with plants components;
- Controlling water and nutrients content in relation to plant requirements.

RECEPTION

- Waste reception should be placed at headworks equipped with the proper outfit for discharging by trucks, compactors, dump boxes or other collection means.
- It should be designed to allow waste stocking for at least 2 days containing, at the same time, the impact linked to the potential odour emissions.
- Design must be carried out on the basis of waste weighed average density, both for compacted and not compacted waste.



PRE-TREATMENT

Substrate preparation section should include the following sections:

- Packages removal section to free the OFMSW from packages: this operation is carried out on the original waste by specific machines without waste comminution;
- Iron separation: this operation eliminates ferromagnetic materials from the main stream and is carried out with electromagnets;
- Inert and plastic materials removal: it removes not biodegradable fractions and is carried out by dry separation, shredding and homogenization by hammer mills;
- Homogenization and water content control: this operation controls the OFMSW characteristics in relation to the process and is carried out in a stirred side tank (wet process) or in stirred hoppers (dry process).



PRE-TREATMENT

Substrate particles size acts directly on the process yields in terms of contact surface between microorganisms and substrate.

Particles size reduction can be carried out by trituration prior to anaerobic digestion or during the digestion process itself by recirculating the biomass through shredding pumps.

A proper particles size derives from a compromise between management and maintenance costs and process efficiency.

PRE-TREATMENT

Water content control

- In wet processes solids content is relatively low (<8% TS) and the substrate dilution is necessary.
- Water content control is performed with sludge or service water.
- In semi-dry processes solids content is, in the optimal range, around 15% while, for dry processes, the optimum is higher than 15%.
- In general, a control stage for substrate solids content should be planned.

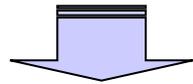
Shredding and reduction



Separation

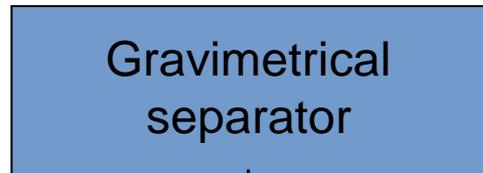
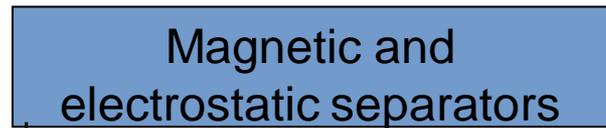
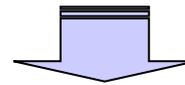


Homogenization



Slow cutting mill
Hammer mill

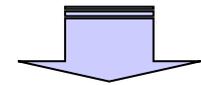
Belt Separator
Trommel separators
Induced current separators



Air Classifier
Fluized bed Classifier
Ballistic Separators



Rotating drum screen
Vibrating screens
Disc screen



Screw mixer
Hydropulpers
Wet mixer

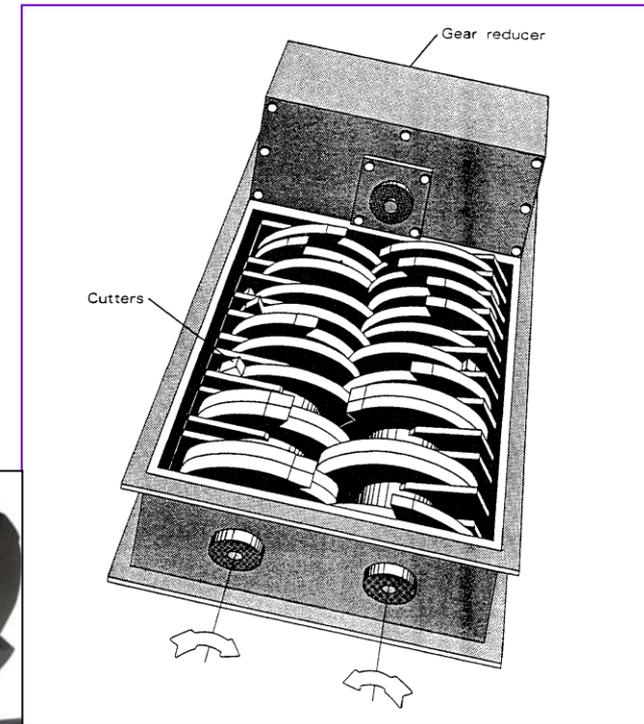
To shred material in entry, to rip bags, to tear the textile materials and to shred the plastic or wood manufactured. Can be mono rotor or bi rotor.

SLOW CUTTING MILL

Production of small sized reduction (<200 mm)

FEATURES:

- blade thickness of 40-50mm;
- One or more horizontal rotors, at variable distance;
- rotation speed between 10 and 50 rpm;
- automatic systems to avoid clog.



HOW TO CHOOSE A SHREDDER:

- final particle size
- managing costs (i.e. electrical consumption)

Usually, to quantify the energetic consumption related to size reduction, it's possible (in approximation), to use the Kick's law:

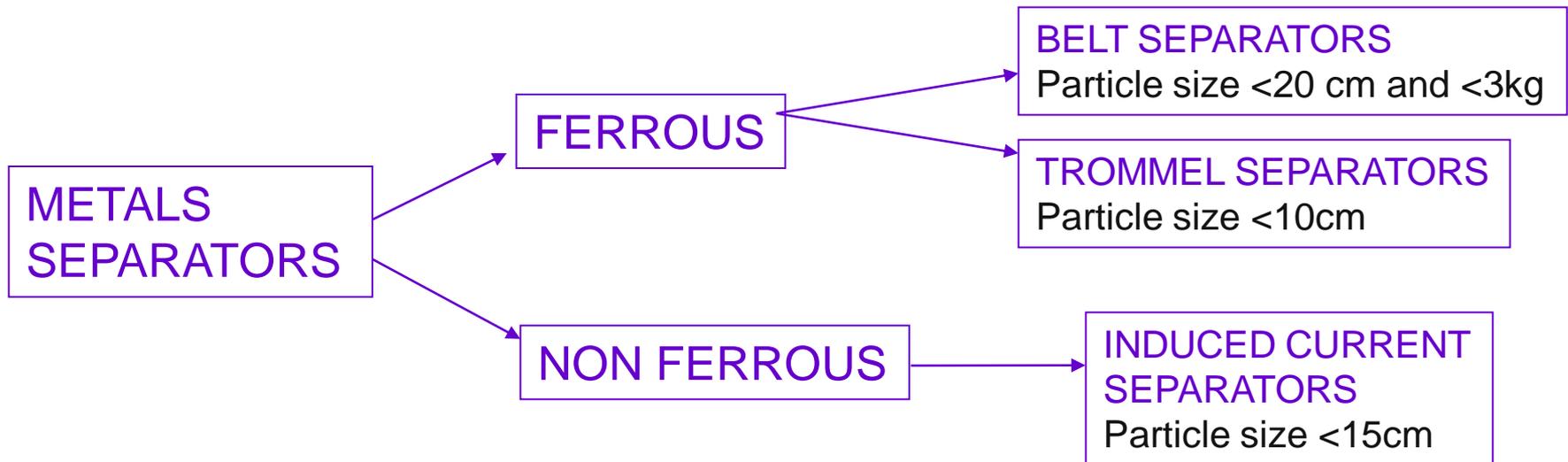
$$E = C \ln \frac{l_1}{l_2}$$

E= specific energy consumption [kWh/ton]
C= constant [kWh/ton]
L₁= initial particle size
L₂= final particle size



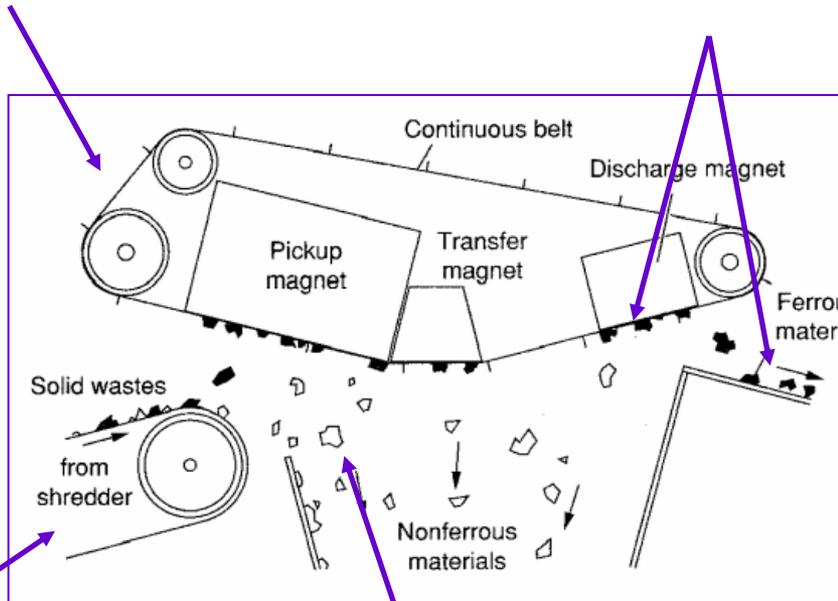
This law is used to make a “scale-up” in order to evaluate the energy consumption when is necessary to change from one size to another.

- 1) Raw materials recovery
- 2) Avoid instrument abrasion



Magnete is located between the two belt's moving rotors, at about 30-40 cm

Ferrous waste remain on the belt and carried into a recovery zone



Waste is transported by a conveyor belt

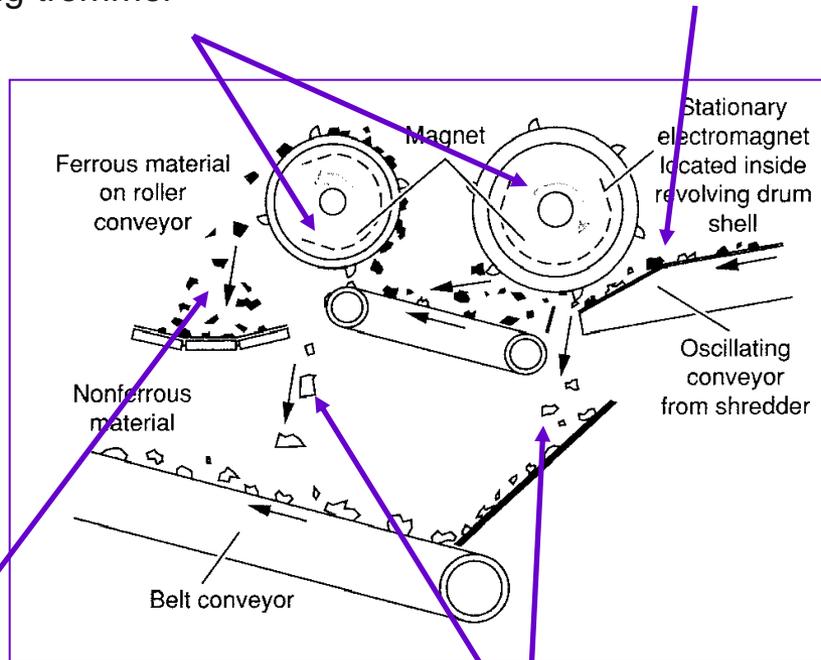
Non ferrous waste fall down after the first conveyor belt

BELT SEPARATORS



Magnete is located inside
a rotating trommel

Waste is transported by a
conveyor belt



TROMMEL SEPARATOR



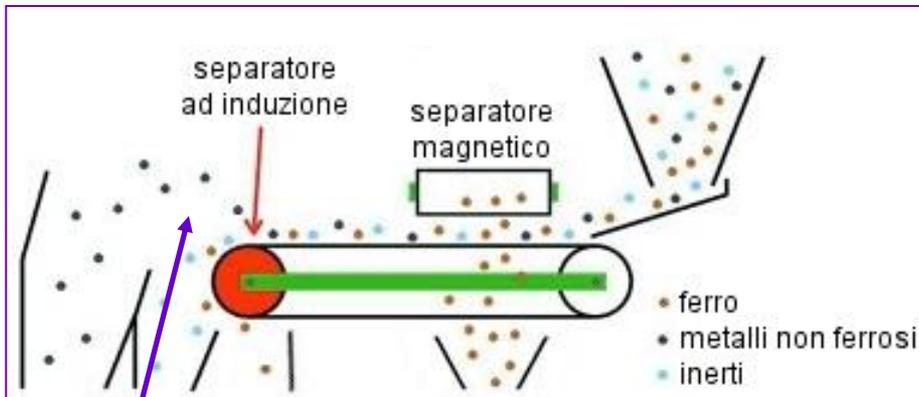
Ferrous waste remain on the
belt and carried into a
recovery zone

Non ferrous waste fall down

Recovery of non-ferrous metals such as aluminum, copper, pure stainless steel, brass, etc. ...

METALS SEPARATORS

INDUCED CURRENT SEPARATORS or ECS (Eddy Current System)



The metal components exposed to a magnetic field at high frequencies, are crossed by currents of Foucault that create a magnetic field.

It is therefore a force of repulsion that tends to move them away from the source of the magnetic field.



PLASTICS AND INHERTS SEPARATORS

The materials present in the waste are separated from each other by exploiting the different physical properties. The aim is to remove the mass of non-biodegradable waste fractions and thereby reduce the risk of abrasion or blockages and blockages in the process.

SIZE SEPARATORS

Separate materials by size, by passing through one or more holes with the appropriate size

ROTATING DRUM SCREENS

VIBRATING SCREENS

DISC SCREENS

GRAVIMETRIC SEPARATORS

Separate materials using the gravimetric properties

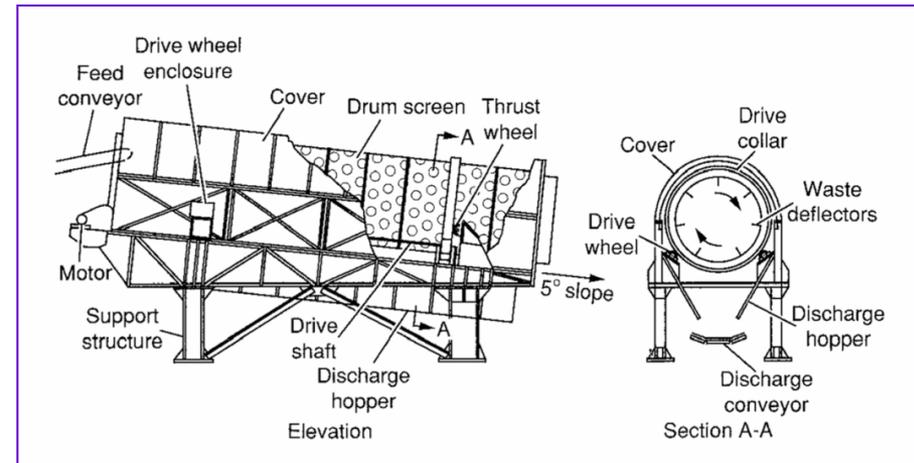
AIR CLASSIFIER

FLUIDIZED BED CLASSIFIER

BALLISTIC SEPARATOR

ROTATING DRUM SCREEN

The smaller particles (sizes vary between 2 and 10 cm, depending on the diameter of the holes of the mesh) pass through the wall of the sieve and are collected in the hopper below (undersize), while the coarser material, remaining inside of the screen reaches the other end of the drum (oversize).



They are characterized by:

- length
- Drum diameter
- Inclination
- Rotation speed
- Mesh opening



VIBRATING SCREEN

FEATURES:

- Fixed support frame;
- Swinging crate equipped with a perforated screen at the base;
- Perforated plates, with hoppers for collecting material.

The size distribution of the product depends on:

- Amplitude;
- Frequency of the oscillations;
- Inclination of the plane;
- Size of the holes (2 to 10 cm).



DISC SCREEN

FEATURES:

- More rotary axes parallel (horizontal)
- Axes mounted disks of varying shape (oval, hexagonal, etc. ...),

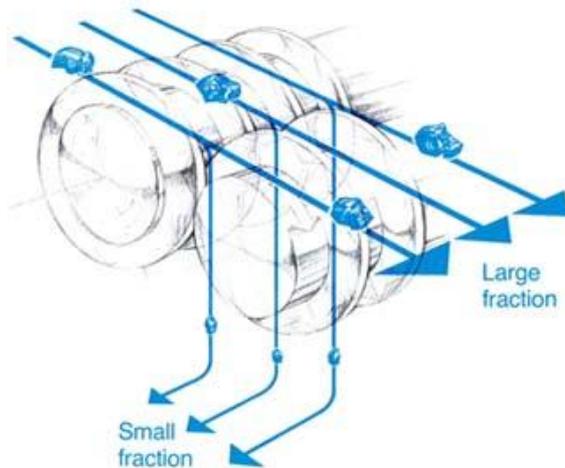
The larger pieces are driven by the rotation of the discs along the screen deck to the exit of the machine, while the finest and heavy materials pass through the sieve and fall into a special compartment for the collection.

DISC SCREEN

FEATURES:

- More rotary axes parallel (horizontal)
- Axes mounted disks of varying shape (oval, hexagonal, etc. ...),

The larger pieces are driven by the rotation of the discs along the screen deck to the exit of the machine, while the finest and heavy materials pass through the sieve and fall into a special compartment for the collection.



AIR CLASSIFIER

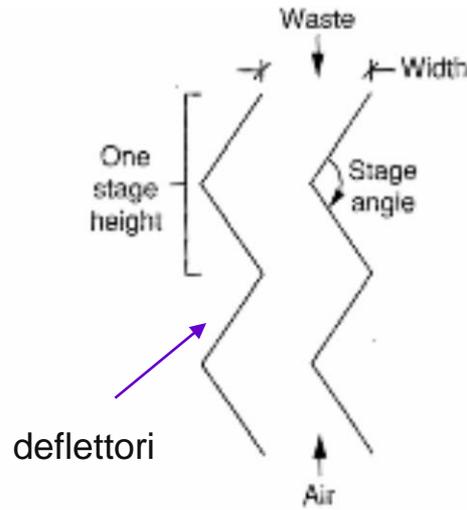
The waste together with air are fed into channels which may have different conformations:



Vertical column

Efficiency:

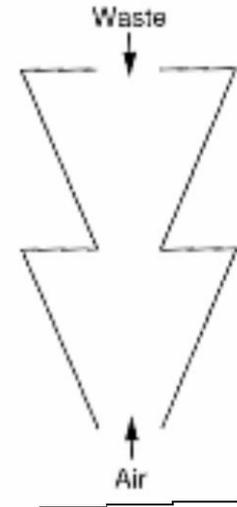
- Air flow rate;
- Section of the column;
- Waste flow rate.



"zig-zag" column

Features:

- Turbulence created by the deflectors.
- Further breakdown of particles



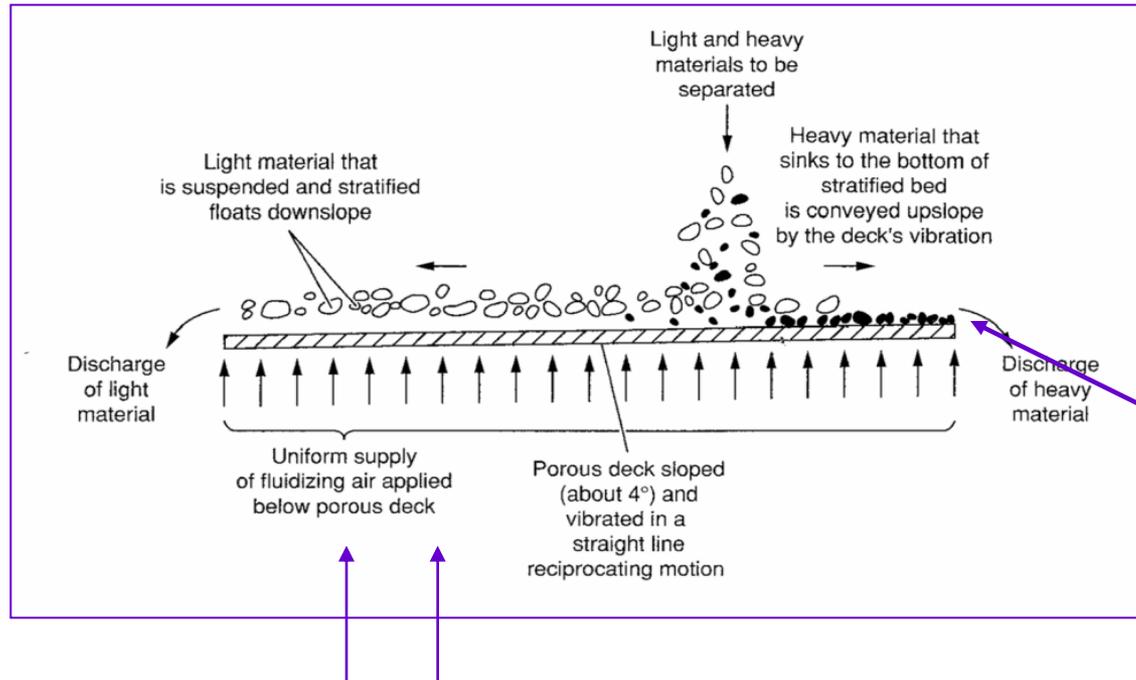
Pulsing air

Features:

- The air does not flow steadily.
- The different speeds facilitate the separation of the waste

FLUIZED BED CLASSIFIER

vibrating surface porous and slightly tilted (about 4°) is crossed by a stream of air



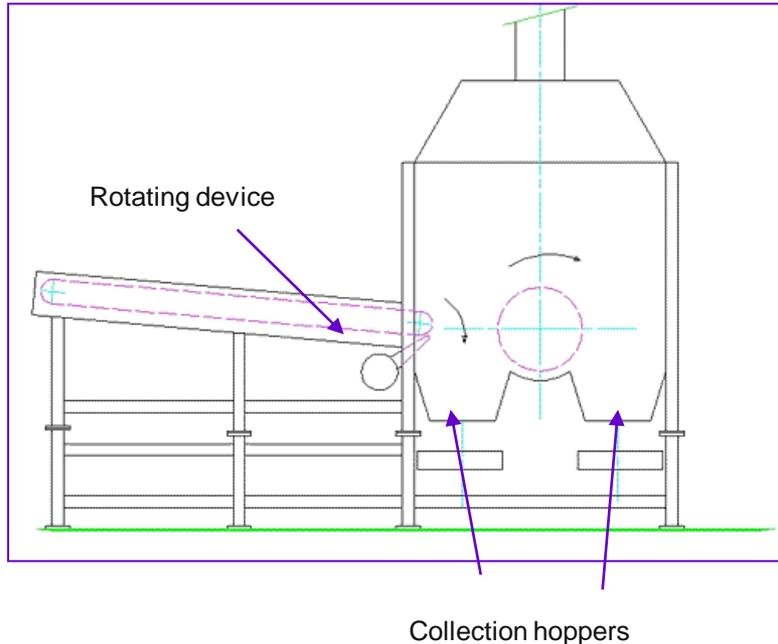
The air and the vibration causes a thinning and layering effect of the refusal

Due to fluctuations the heavier material is dragged toward the top

The blown-in air suspension keeps the lighter material being dragged down

BALISTIC SEPARATORS

Perform the separation of parts of the treated waste by exploiting differences in density and elasticity between each of these



Density differences:

- The waste is loaded into a special hopper and taken in small quantities;
- A rotating device gives a sharp acceleration to the waste, projecting it above the mouths of hoppers placed at different distances, at the base of a closed chamber.

Differences in elasticity:

- a rotating high-speed throw the waste against a rubber disc that rotates in a plane orthogonal to the direction of launching;
- The waste bounces on this plan and depend on its elasticity, it is collected in different rooms.

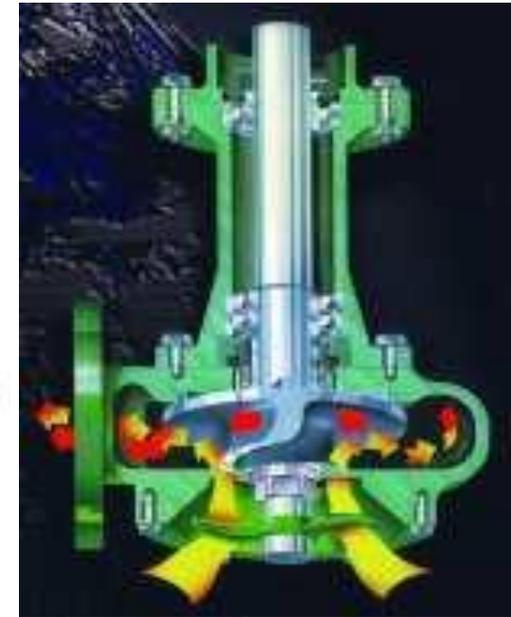
1 To make the size compatible with anaerobic digestion process to ensure adequate surface contact with the microorganisms

2 To make the size compatible with equipment used for handling the mixture

The perfect size does not exceed 10-20 mm

Are used:

- Cutting Mills
- Online lacerating pumps on the recirculation stream of the biomass



HOMOGENIZATION

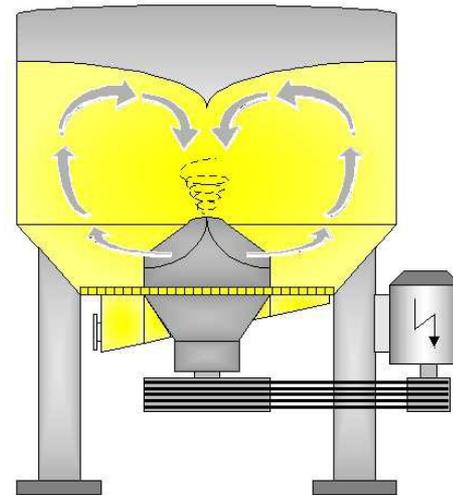
This operation is necessary both to ensure the proper functioning of the process and to optimize the yields of methane, both to handle the material more easily, especially in dry processes or semi-dry.

The most commonly used types of mixers are:

screw mixers for dry processes or semi-dry;



Hydropulper processes for semi-dry or wet.

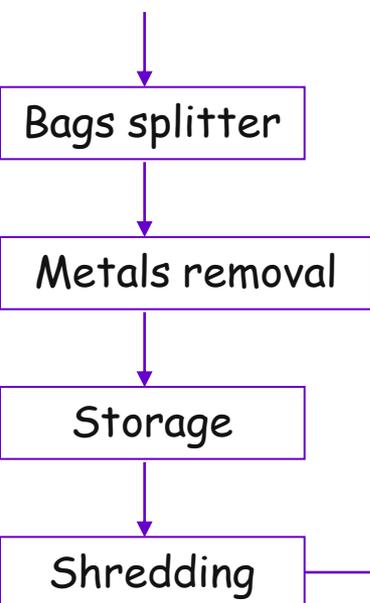




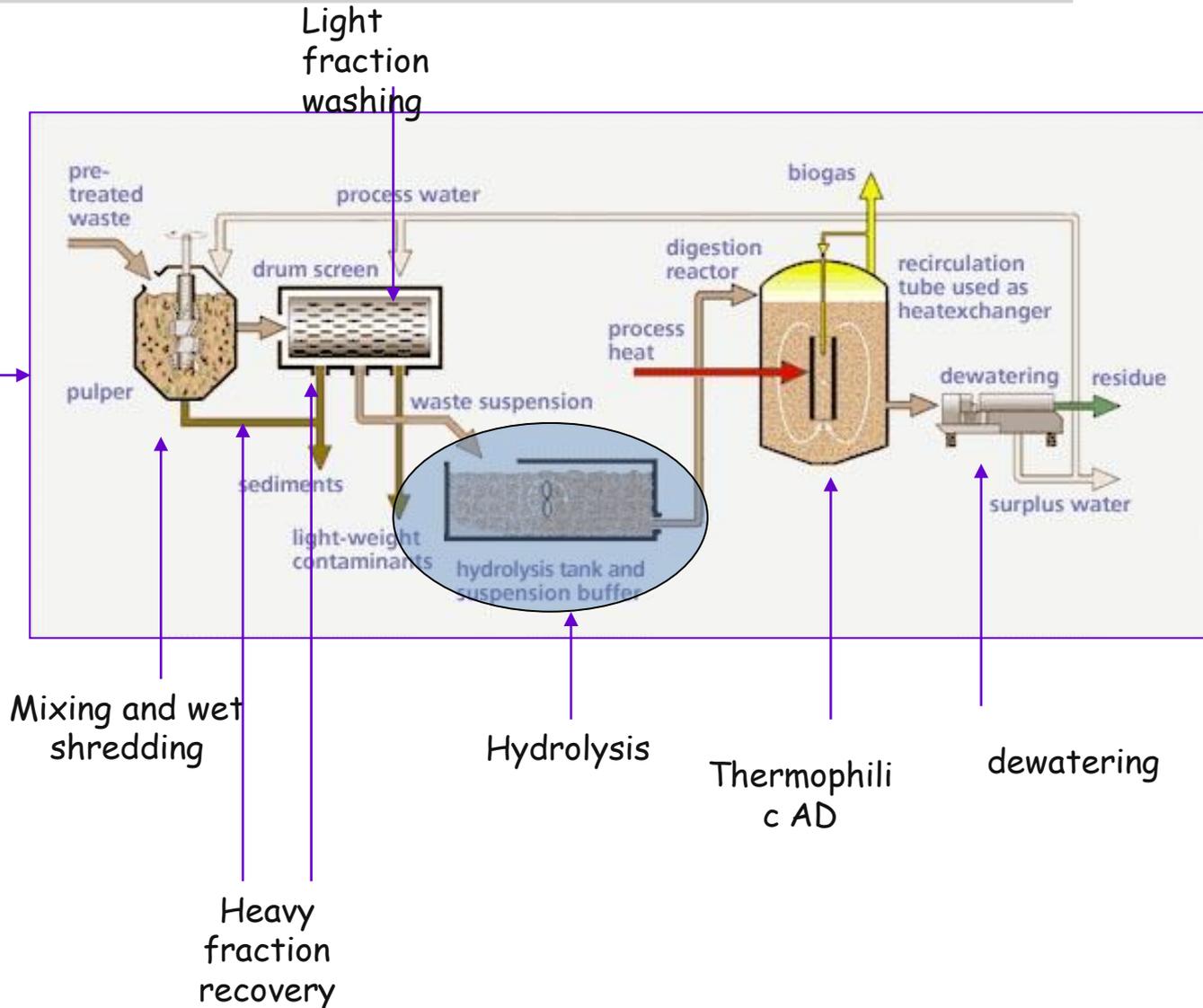
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TREATMENT FLOW SCHEMES: FULL SCALE APPLICATIONS

OFMSW-SC



<100 mm





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Waste streams characterization

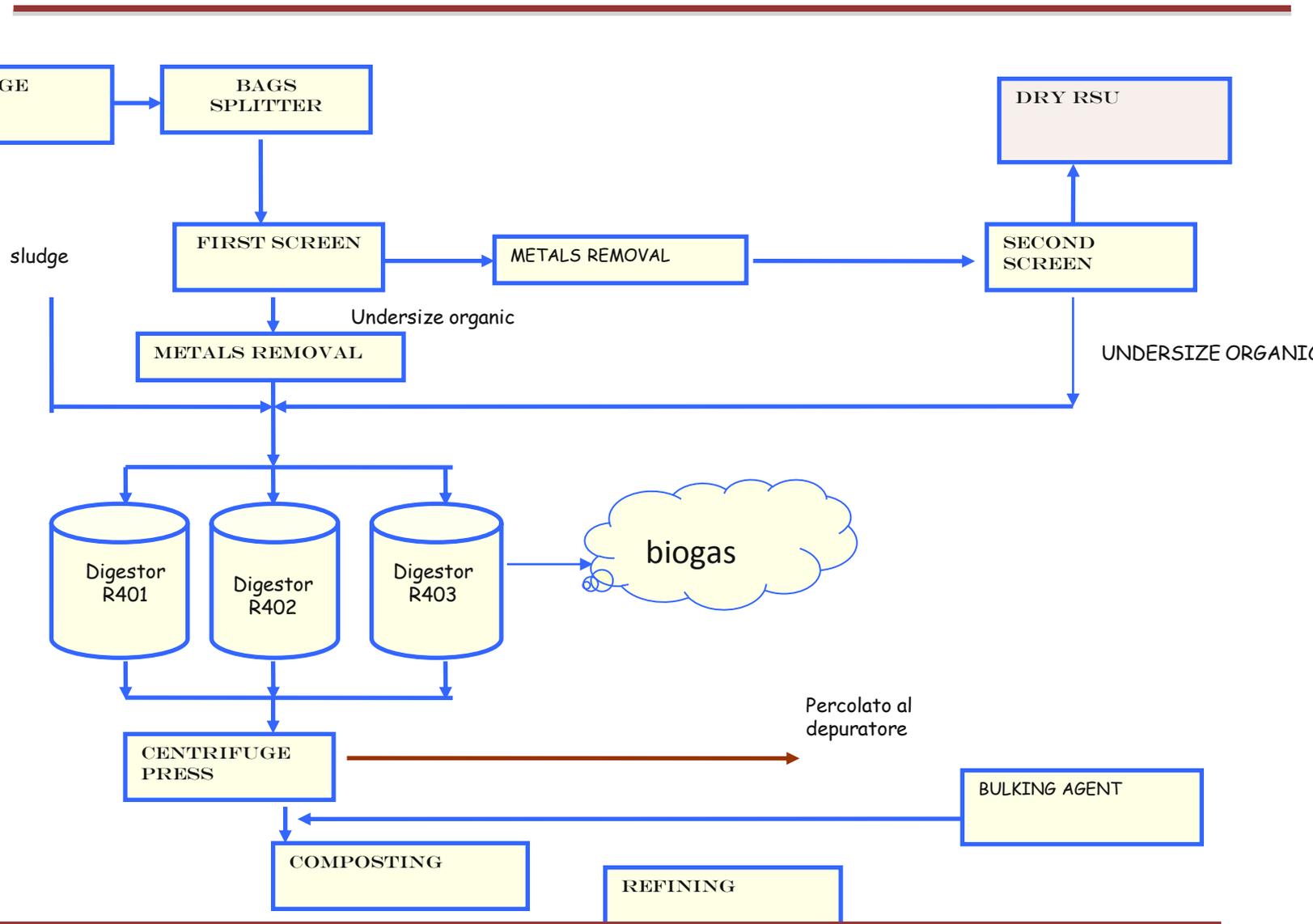
Stream	%TS	TVS, %TS	
wet	26,1	84,0	
pulp	8,3	84,0	
Zootecnical waste	5,8	73,5	
Light fraction	41,3	93,9	
Heavy fraction	65,0	20,8	
Hydrolized waste	4,8	82,7	

Substrate fed	OFMSW, sewage sludge, cattle manure	
t/d	200 (5 days per week)	
OFMSW (t/y)	13.000 (data 2006)	
Organic (w.w. %)	97%	
digestion (wet, dry, semi-dry)	wet	
OLR kgTVS/m ³ d	3	
HRT, d	22	
Volume (m ³)	3.000	
Temperature(° C)	53-55	
Yields		
GP, m ³ /d	5.000	
Biogas composition (CH ₄ , %)	58-60%	
Specific gas production m ³ /kgTVS	0.55	



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OFMSW-
SC, grey
waste,
OFMSW-
MS





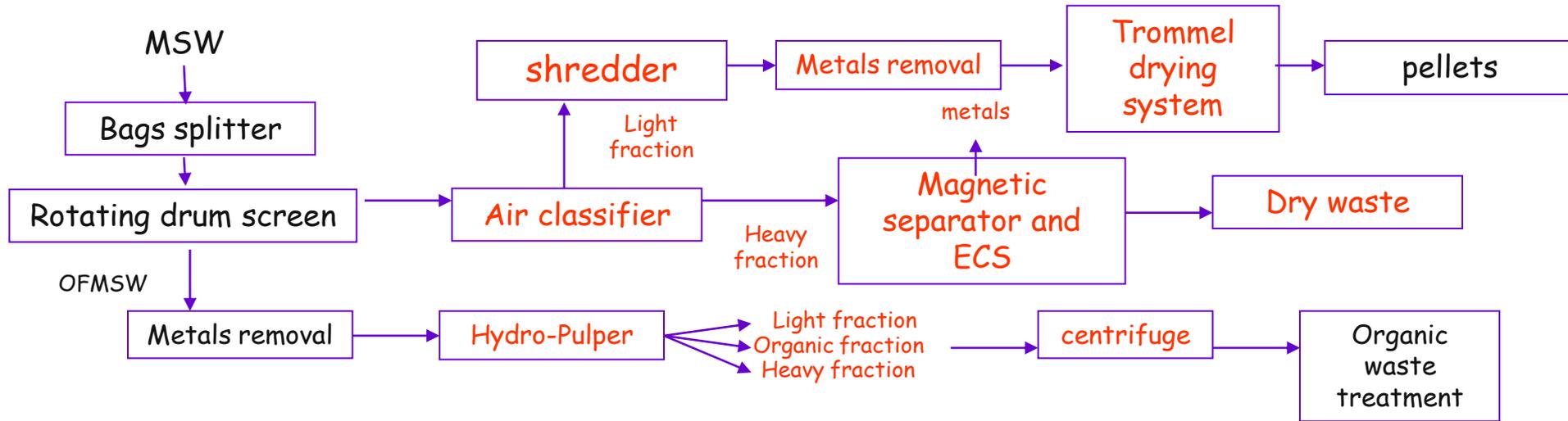
Bassano (VI) WWTP

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Waste characteristics

CONTENT %	OFMSW-SS	"grey waste"
Organic	70-83	10-16
Cellulose	7-12	34-50
Plastic	4-9	24-34
Metals	0-1	1-9
Glass and inert	1-4	2-14
Wood and textile	1-3 1-6	3-8 2-4
TS%, ww	25-42	67-94
TVS, %TS	69-77	69-91

Substrate	SS-OFMSW, grey waste, MS-OFMSW
t/d	90 (6 days/week)
OFMSW (t/a)	24.000
Organic (w.w. %)	94%
digestion (wet, dry, semi-dry)	Dry
OLR kgTVS/m ³ d	5,8 ~ 7,7
HRT, d	30 ~ 35
Volume (m ³)	1.500 x 3
Temperature (° C)	37 ~ 38
Yields	
GP, m ³ /d	11.000 ~ 12.000
biogas composition (CH ₄ , %)	58-60
Specific gas production m ³ /kgTVS	0.7-0.2

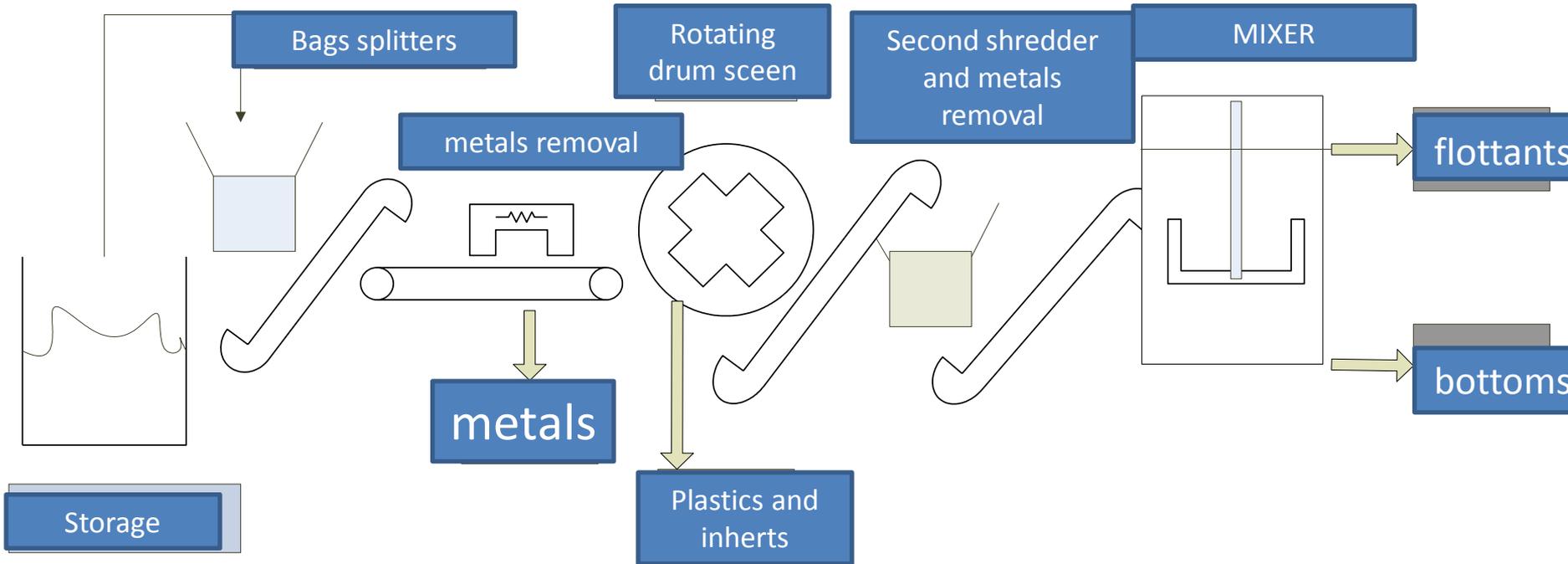


SGP < 0,3 m3/kgTVS

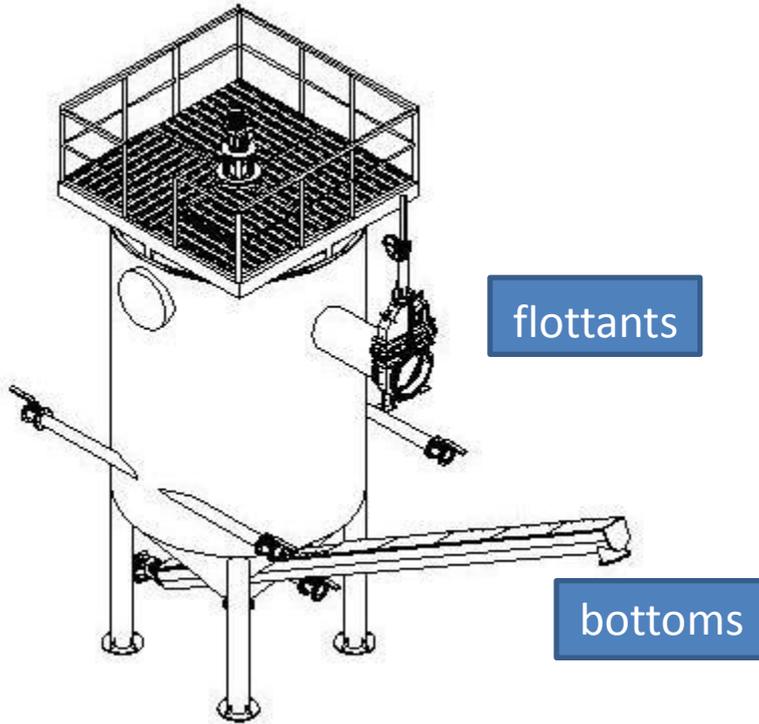




Substrate fed	SC-OFMSW
t/d	10-20
OFMSW (t/y)	2500
Organic (w.w. %)	59
digestion (wet, dry, semi-dry)	Wet
OLR kgTVS/m ³ d	1,2
HRT, d	22
Volume (m ³)	2000
Temperature(° C)	35
Yields	
GP, m ³ /d	1080
Composition (CH ₄ , %)	63
Specific gas production m ³ /kgTVS	0,45

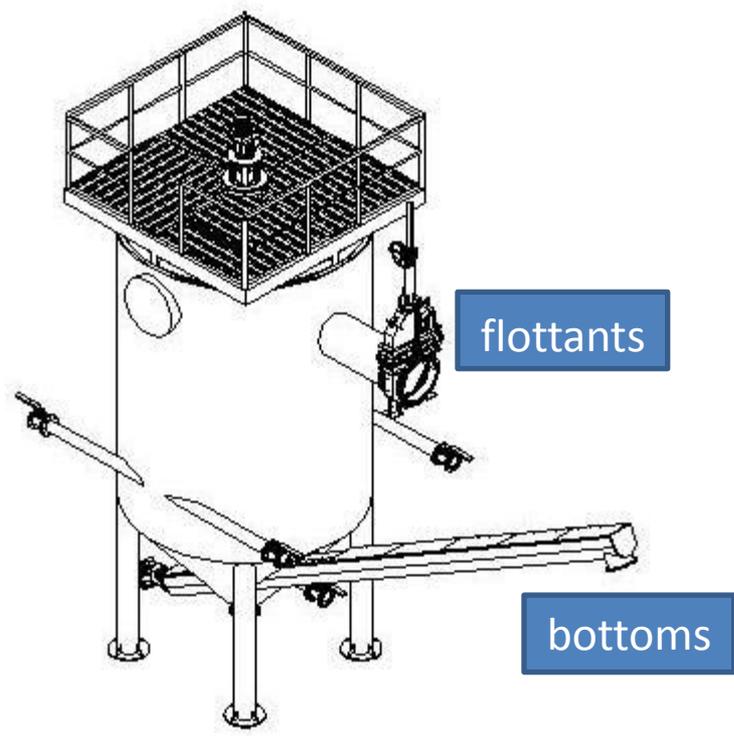


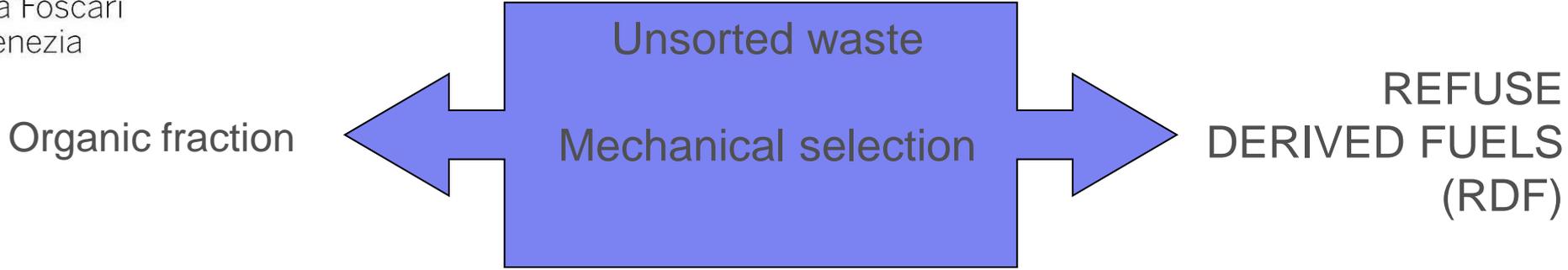
Organic capture: 76% Plastic capture: > 90% Metals capture: 99%





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	TS, g/Kg	TVS, %TS	N, %TS	P, %TS
MS-OFMSW	500-700	40-50	1,5-3	0,05-0,2
SS-OFMSW	170-250	70-90	-	-
SC-OFMSW	70-150	80-90	1,5-3	1-3

OFMSW yields vs. collection approach



Electric energy efficiency index:

ratio between the electric energy produced and consumed in the treatment per ton of organic waste treated

$$\text{EnergyIndex} = \frac{\text{Energy}_{\text{output}}}{\text{Energy}_{\text{input}}} = \frac{kWh_{\text{produced}}}{kWh_{\text{consumed}}}$$

Optimal E.I. value → 10