Powergen Asia 2007 Bangkok - Thailand

Biogas Production from Municipal Solid Waste in Havana, Cuba

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IMTE AG
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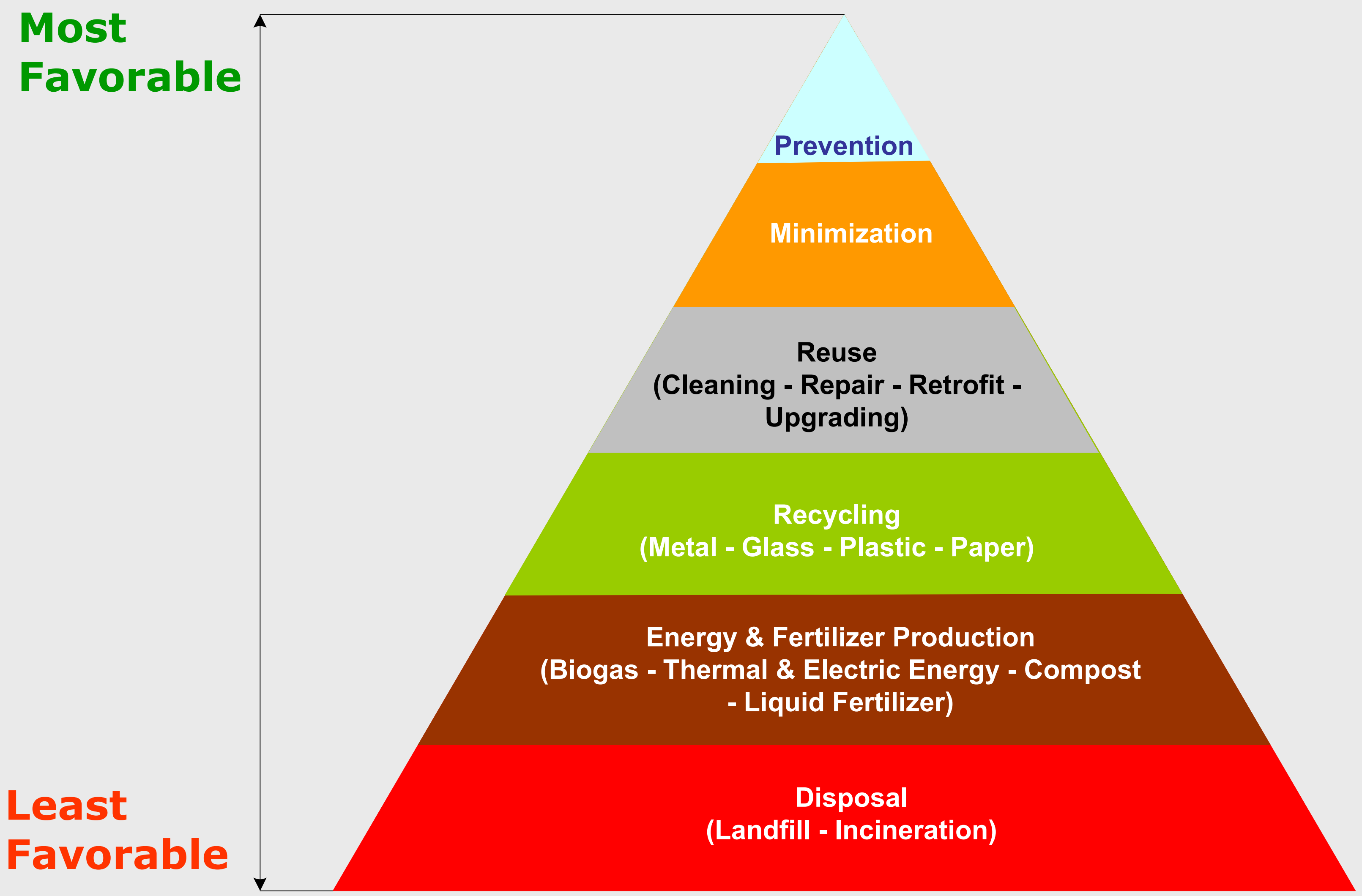
Project Objective

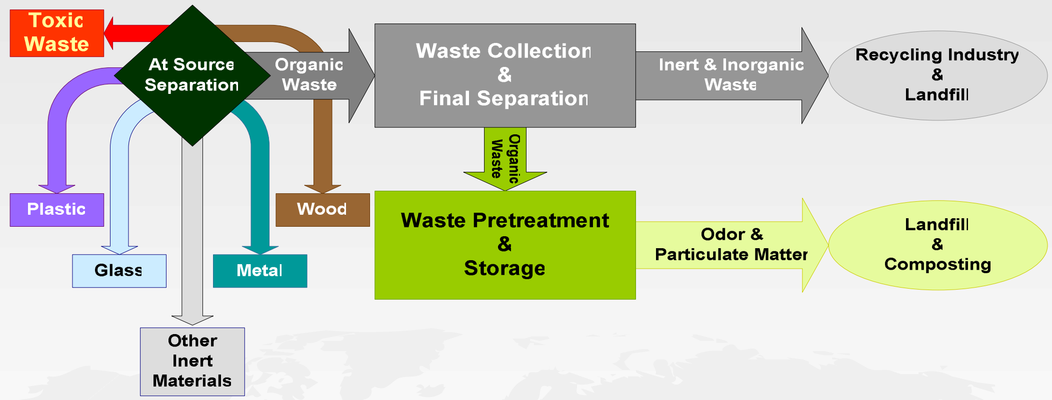
To establish at a pilot level the technical and economic viability of the production of biogas and fertilizer from Organic Fraction of Municipal Solid Waste.

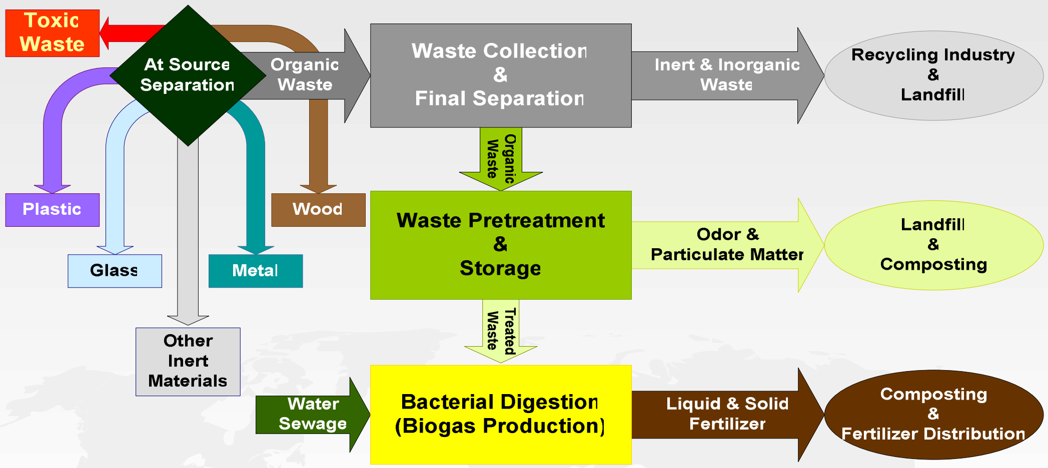
Biodegradable Waste Sources

- The Forest Residue → Heat & Syngas
- Wood Processing Industry → Heat & Syngas
- Urban Wood Waste → Heat & Syngas
- Waste from Agricultural Products Processing Industry → Biogas & Syngas
- Solid & Liquid Animal Slurry → Syngas & Biogas
- Agricultural Plant Waste → Heat, Biogas, Syngas, Methanol & Ethanol
- Other Free Field Residue → Heat & Syngas
- **Municipal Waste**

MSW Hierarchy




Toxic Waste
At Source Separation
Organic Waste
Waste Collection & Final Separation
Inert & Inorganic Waste
Recycling Industry & Landfill
Plastic
Glass
Other Inert Materials
Metal
Wood
Organic Waste
Waste Pretreatment & Storage
Odor & Particulate Matter
Landfill & Composting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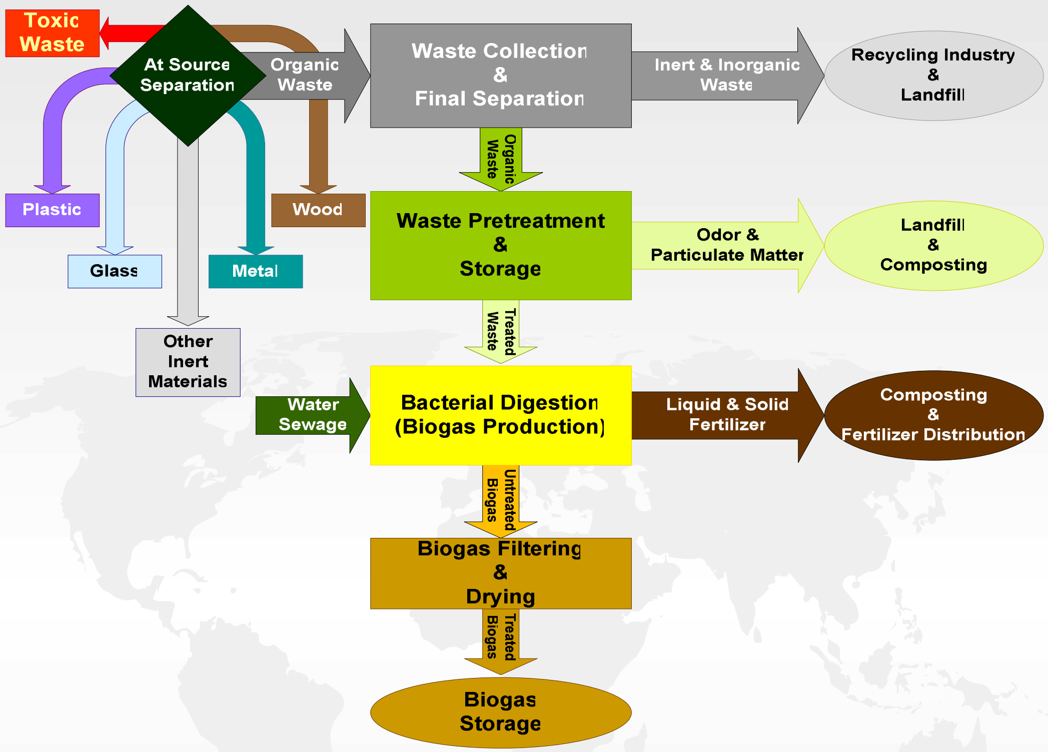
Liquid & Solid Fertilizer
Composting & Fertilizer Distribution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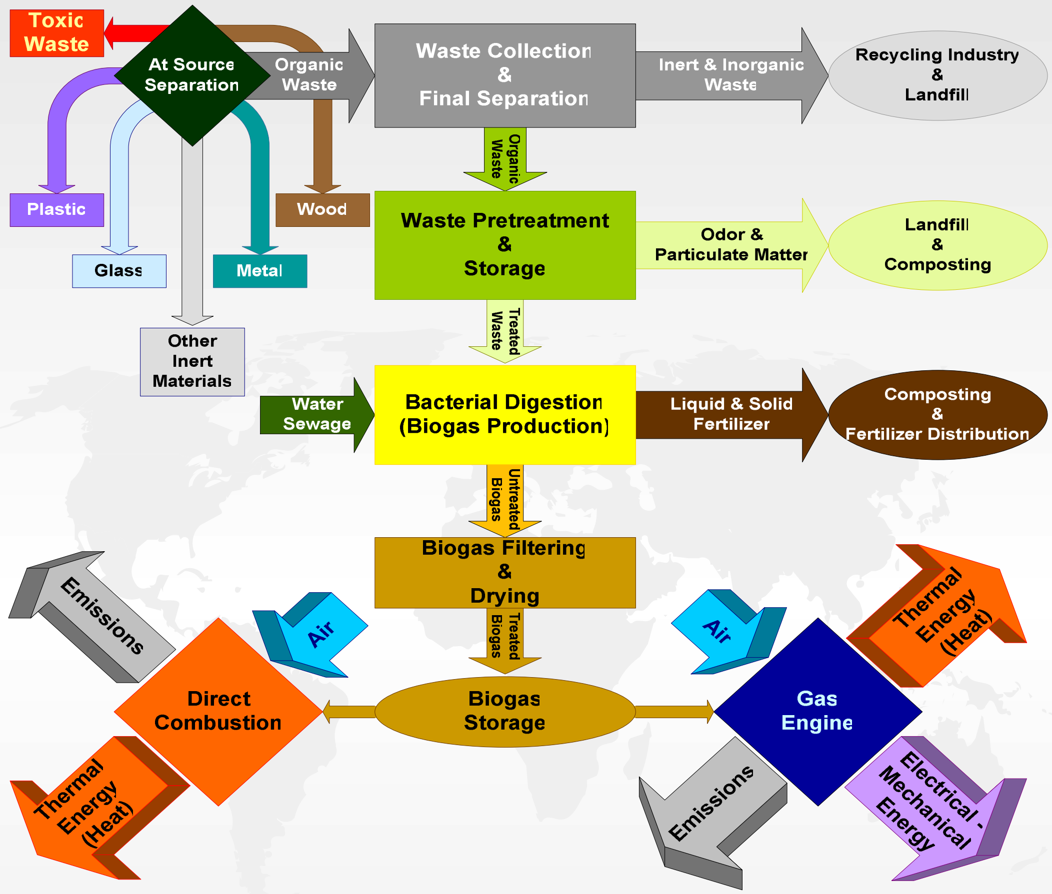
Treated Biogas
Biogas Storage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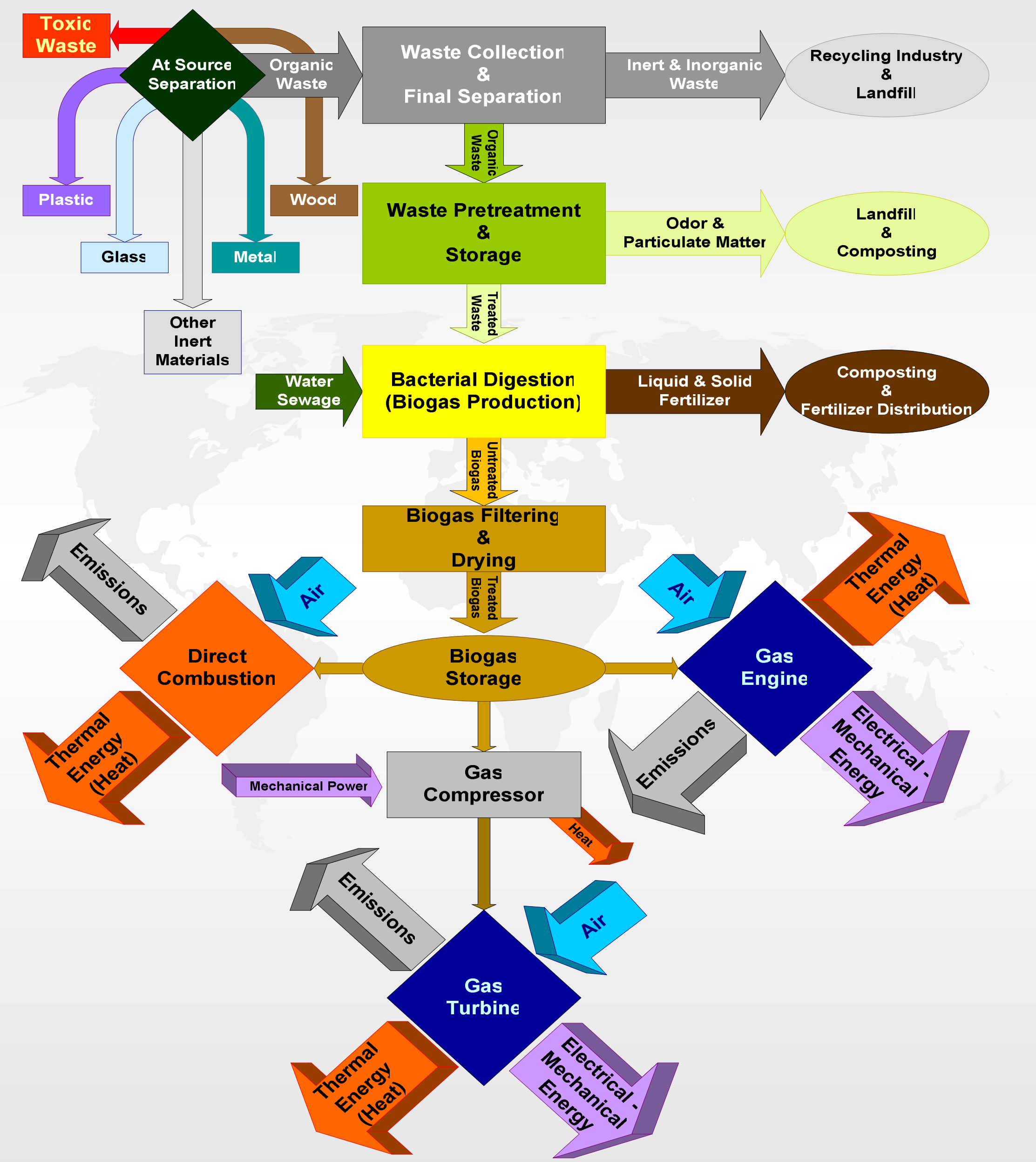
Air
Direct Combustion
Thermal Energy (Heat)
Biogas Storage
Air
Gas Engine
Thermal Energy (Heat)
Emissions
Electrical - Mechanical Energy



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Mechanical Power
Gas Compressor
Heat
Emissions
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Gas Turbine
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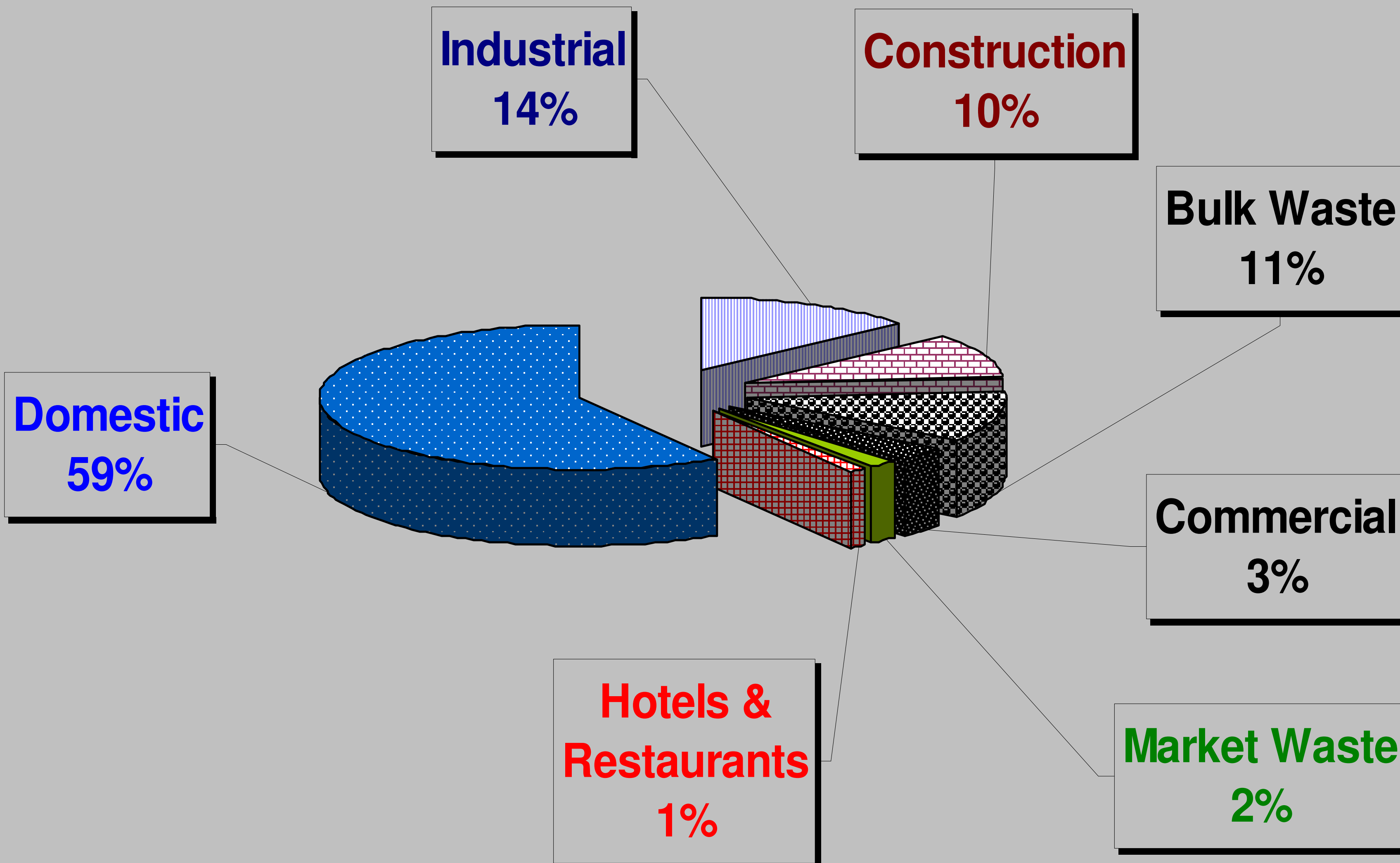
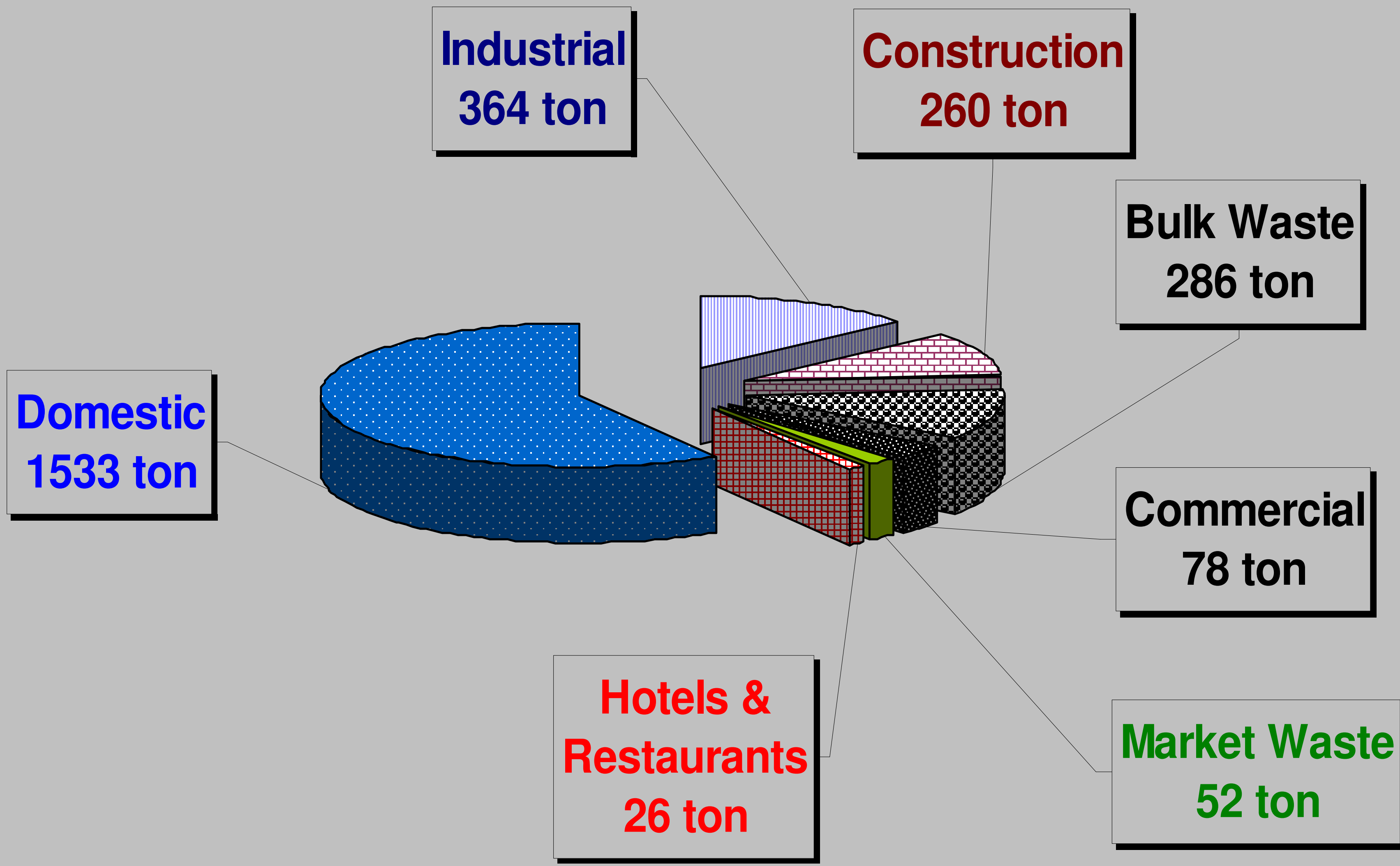
Ratio of Havana's MSW in 2003



Havana's Daily MSW Generation in 2003



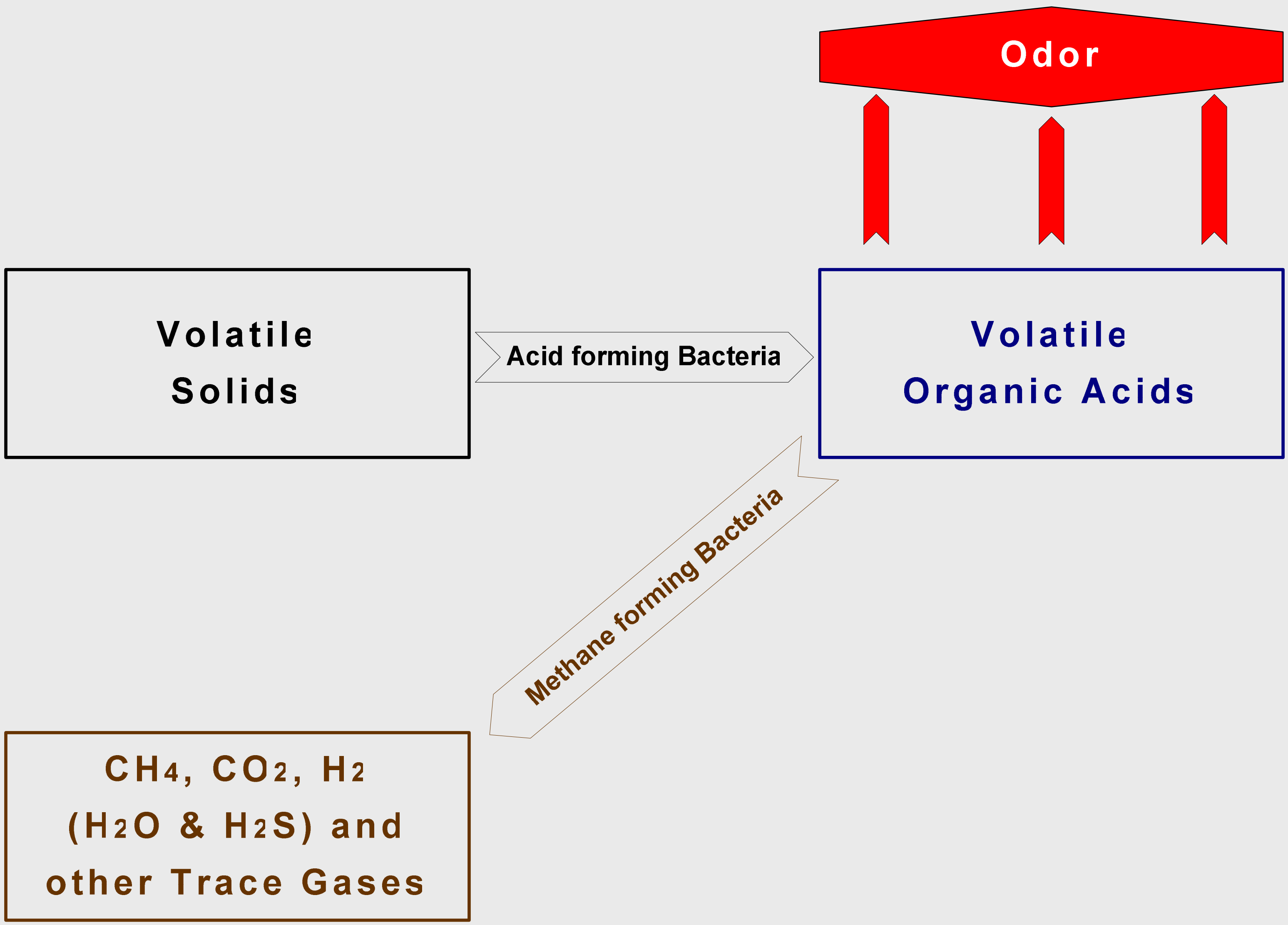
Technology Choice

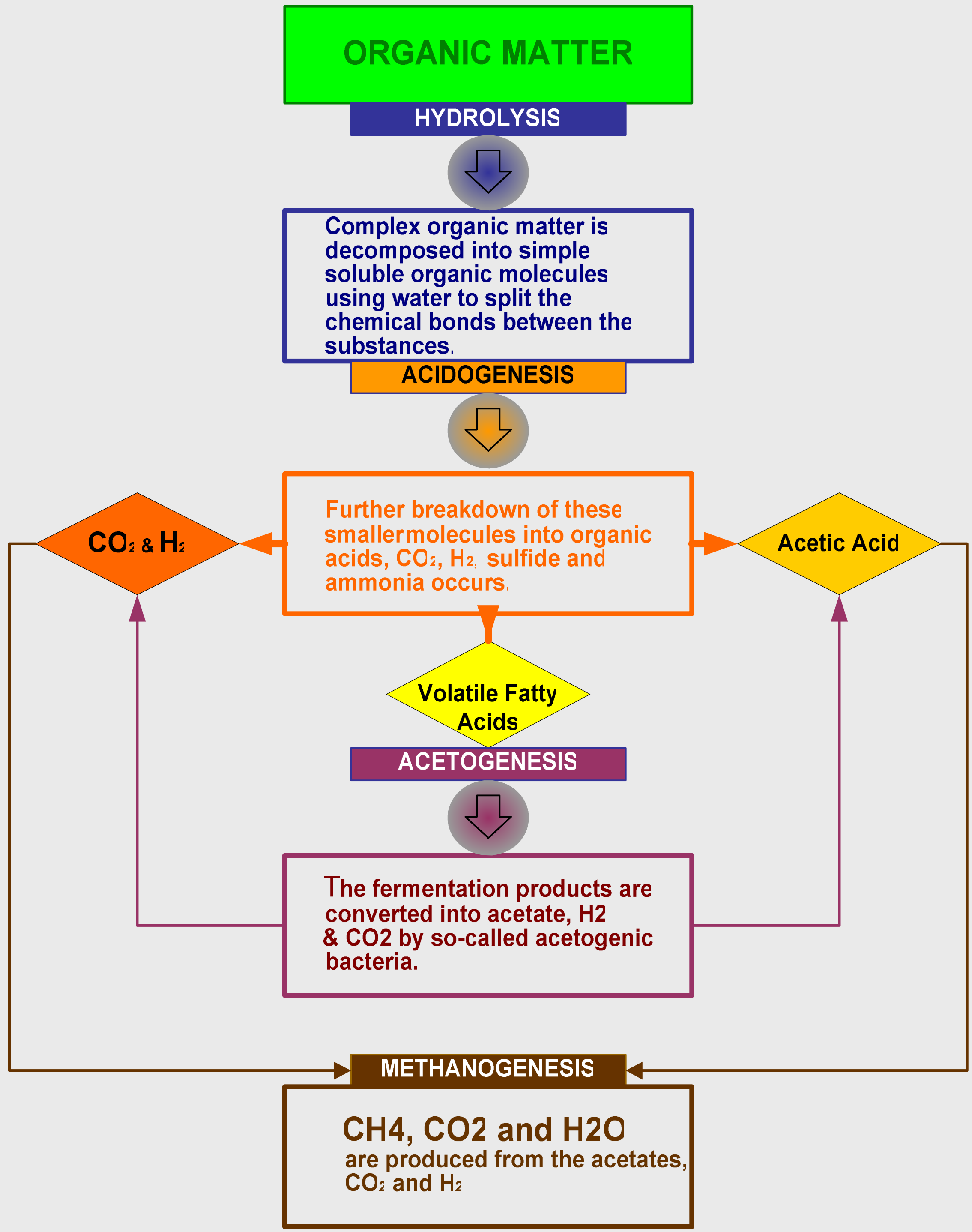
- **Direct Combustion** MAIN PRODUCT → **Thermal Energy**
- **Thermo-Chemical Conversion** MAIN PRODUCT →**Charcoal, Syngas**
- **Briquetting** MAIN PRODUCT → **Dense Combustible Briquettes**
- **Composting** MAIN PRODUCT → **Compost (Fertilizer)**
- **Recycling & Converting** MAIN PRODUCT → **Metal, Glass, Plastics, Paper, Oils, etc**
- **Extracting** MAIN PRODUCT → **Material & Components for Industrial Applications**
- **Cleaning & Special Treatment** MAIN PRODUCT → **Construction & Building Material**

Biochemical Conversion → Anaerobic Digestion Technology

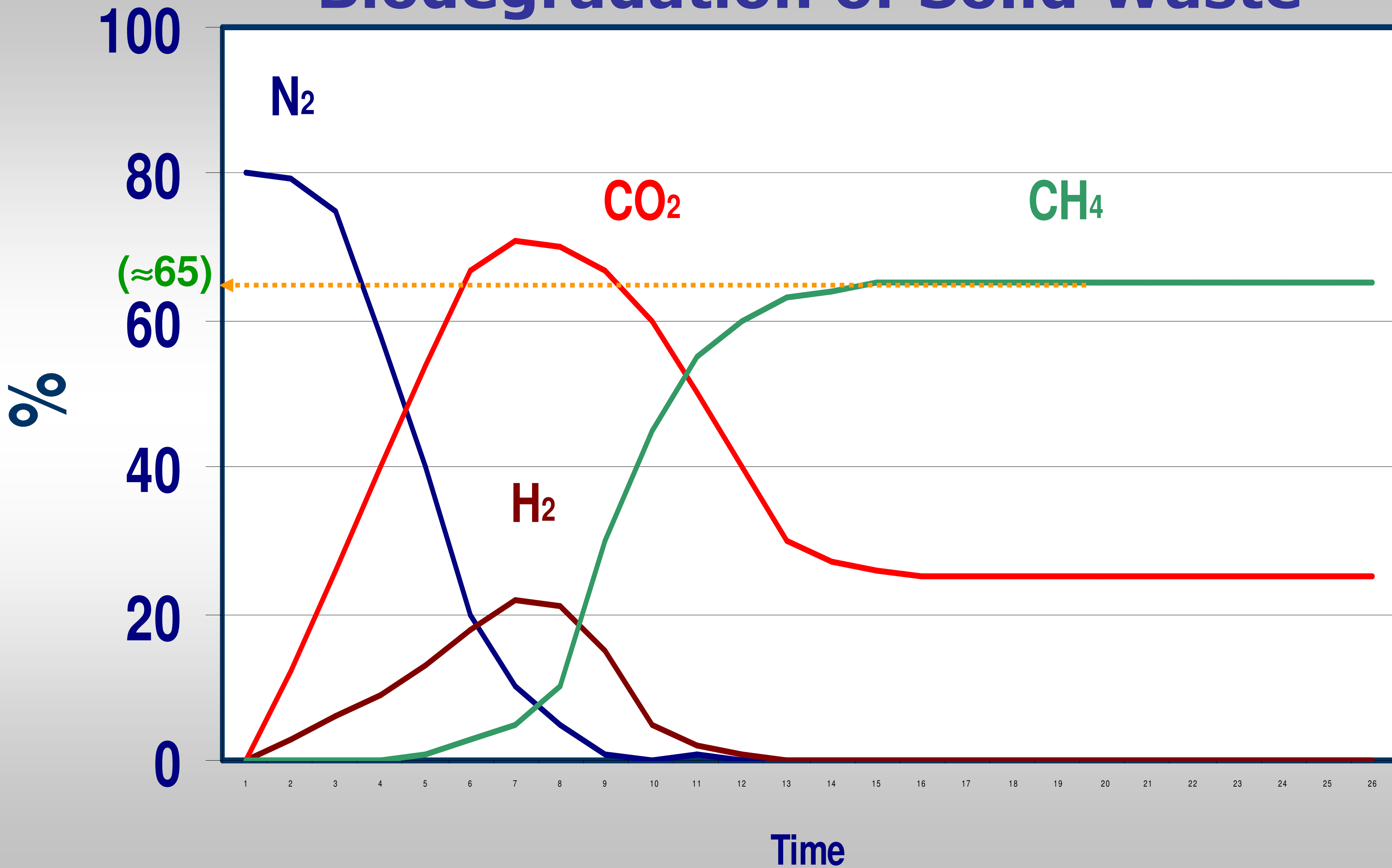
- A versatile and cost-effective bio-waste treatment technology, particularly for the primary treatment of agro-industrial waste, municipal organic waste and high-strength organic wastes in town wastewater;
- Methane-rich biogas produced as a by-product of the process readily exploitable as a bio-fuel for heat and power generation;
- Nutrient recovery from the digested liquor can be used as a fertilizer;
- Low process energy requirement vs. high process stability particularly in terms of toxicants and load changes.

Simplified Digestion Process




ORGANIC MATTER
HYDROLYSIS
Complex organic matter is decomposed into simple soluble organic molecules using water to split the chemical bonds between the substances.
ACIDOGENESIS
Further breakdown of these smallermolecules into organic acids, CO_2, H_2, sulfide and ammonia occurs.
CO_2 & H_2
Acetic Acid
Volatile Fatty Acids
ACETOGENESIS
The fermentation products are converted into acetate, H2 & CO2 by so-called acetogenic bacteria.
METHANOGENESIS
CH4, CO2 and H2O
are produced from the acetates, CO_2 and H_2

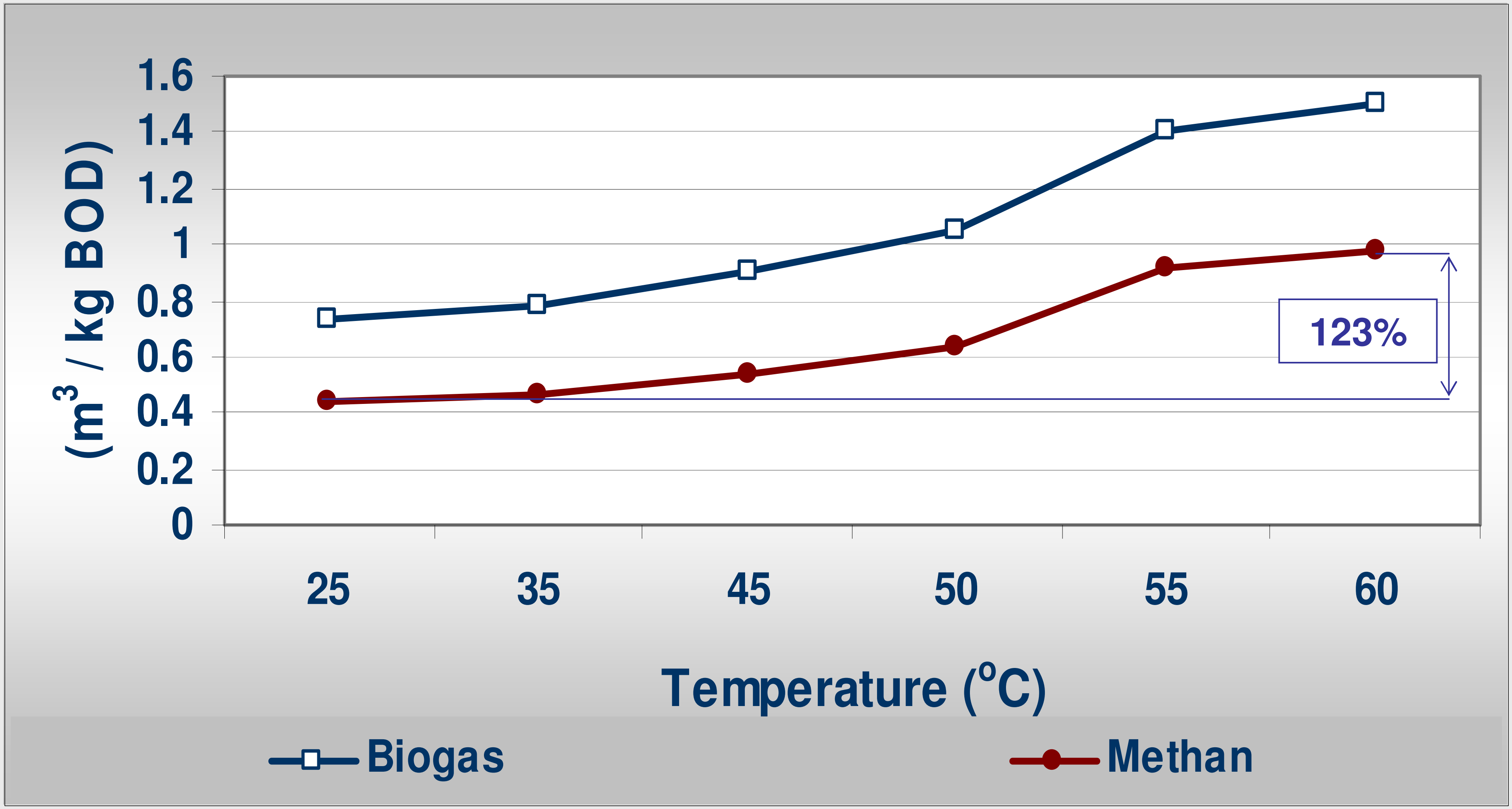
Biodegradation of Solid Waste



Biogas

- Anaerobic Digestion
  Decomposition in absence of O_2
  → Psychrophilic <25°C
  → Mesophilic 25 - 40°C
  → Thermophilic 50 - 65°C
- 55% - 65% CH_4 ** 35% - 45% CO_2
  traces of H_2S ** N_2 ** H_2
- Hu → 20 -24 MJ/Nm^3
  (Natural Gas ~40MJ/Nm^3).

Average Biogas Yield from AD at Various Temperatures



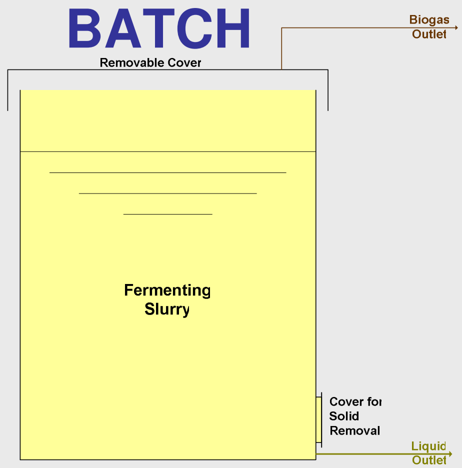
Optimizing CH_4 Production

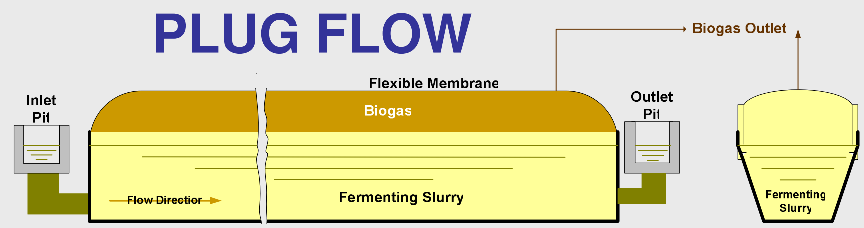
- **Temperature Control**
- **pH Control**
- **Fermenting Slurry Mixing and Recirculation**
- **Separating Bacteria from Effluent and keeping them in Digester**
- **Selecting the appropriate Strain of Bacteria**

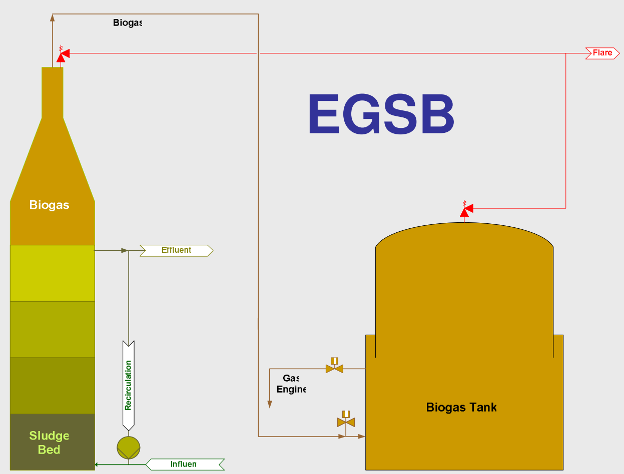
Process Selection

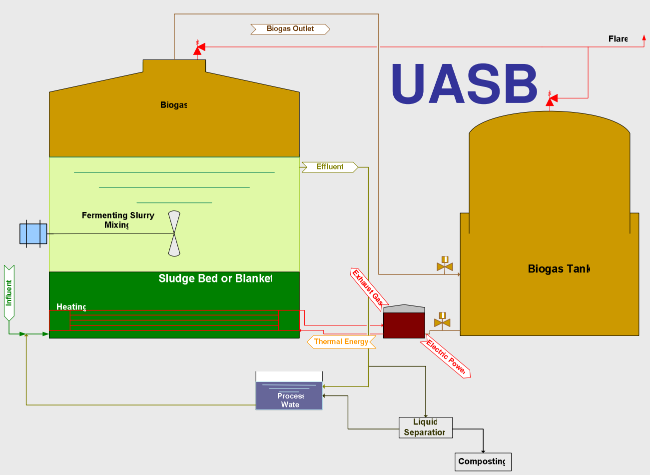
Digestion Process	Description	Advantages	Disadvantages
Dry	Dry solids content of > 25-40%	Compact, lower energy input, better biogas quality (<80% CH_4), maintenance friendly	Restricted mixing possibilities
Wet	Dry solids content of < 15%	Better mixing possibilities	Higher energy input, lager reactor
Psychrophilic	Digestion temperature around 20 - 25°C	Long process time, very slow rate	Minimal energy input
Mesophilic	Digestion temperature between 25 and 40°C	Longer process time, slower rate	Low energy input
Thermophilic	Digestion temperature between 50 and 65°C	Shorter process time, higher degradation, faster rate	Higher energy input Temperature control
Batch	Substrate in closed reactor during whole degradation period	Suitable for small plants with seasonal substrate supply	Unstable biogas production
Continuous	Reactor is filled continuously with fresh material	Constant biomass production through continuous feeding	

Technology Choice

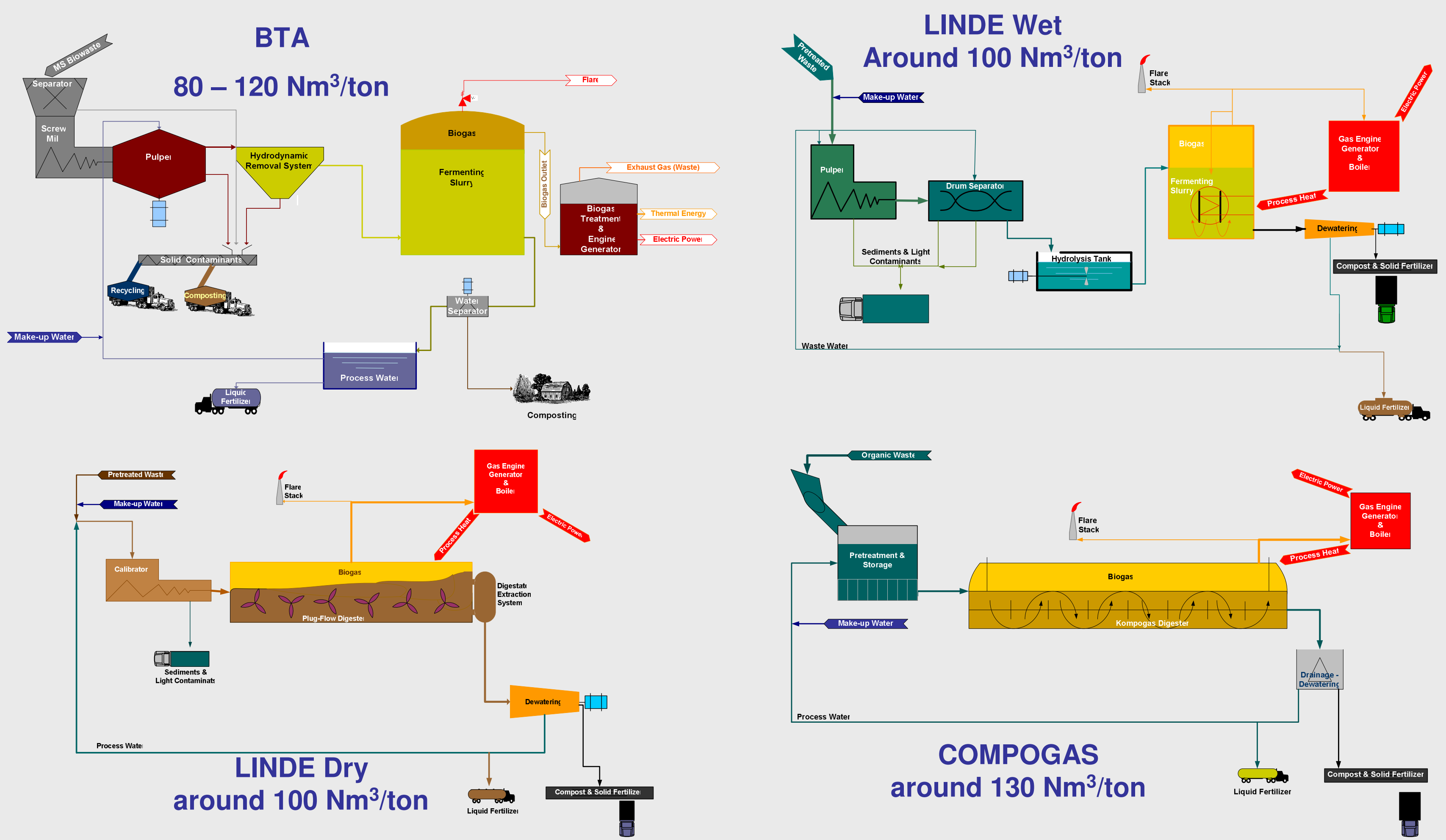






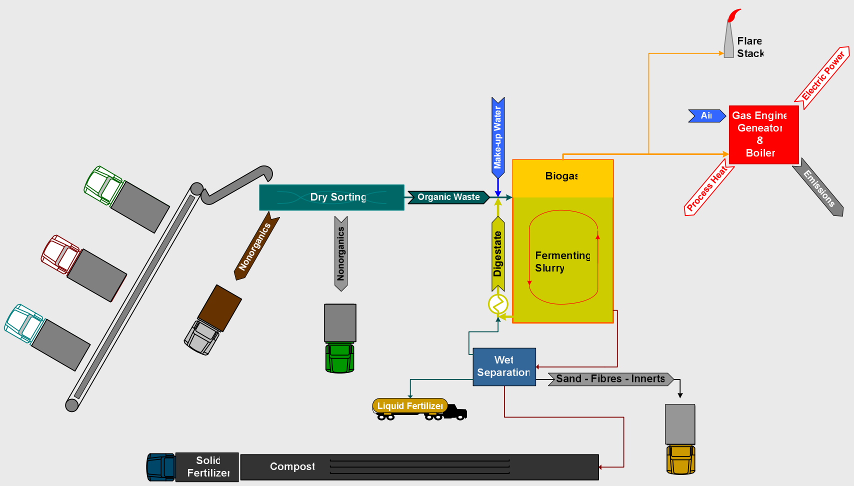


Technology Choice

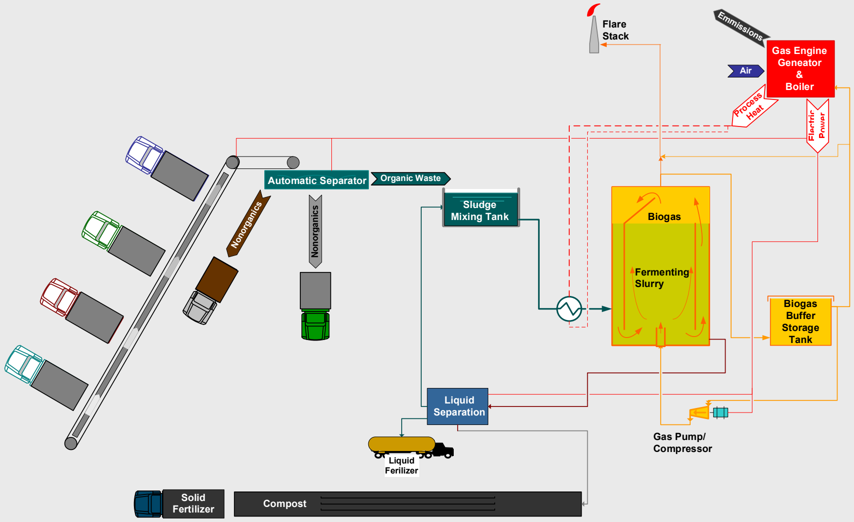


Technology Choice

DRANCO
110 – 200 Nm^3/ton



VALORGA
80 – 160 Nm^3/ton



Valorga Technology

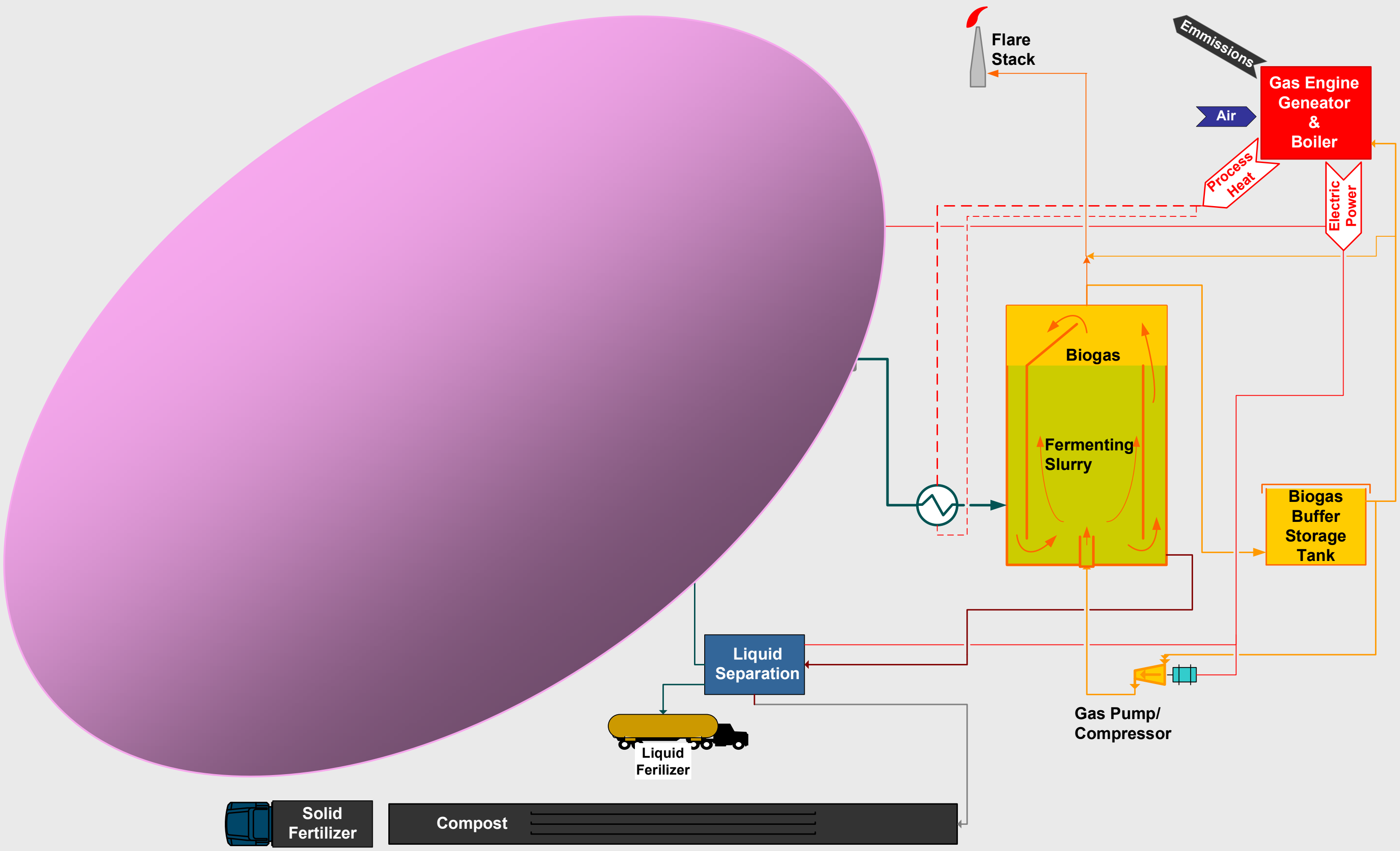
- Up to date, more than 2 million tons of MSW was treated with Valorga process
- Process designed for treatment of mixed MSW
- Valorga process plant consists of 5 units

1 MSW Reception and Preparation Unit
2 Anaerobic Digestion Unit
3 Biogas Storage and Treatment Unit
4 Biogas Utilization Unit
5 Compost Curing Unit

Valorga Technology

1 MSW Reception and Preparation Unit;

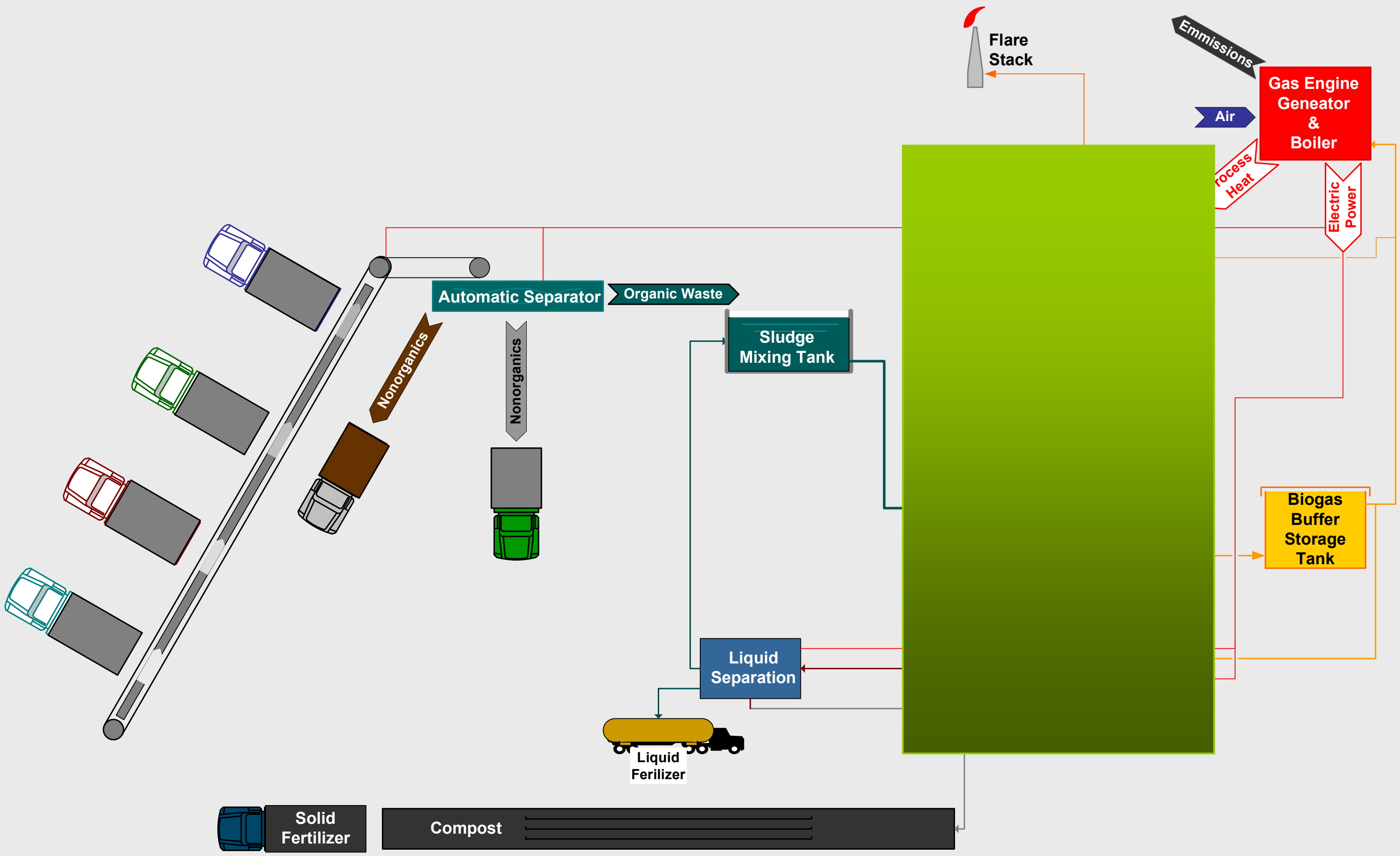
Valorga Technology



Valorga Technology

2 Anaerobic Digestion Unit

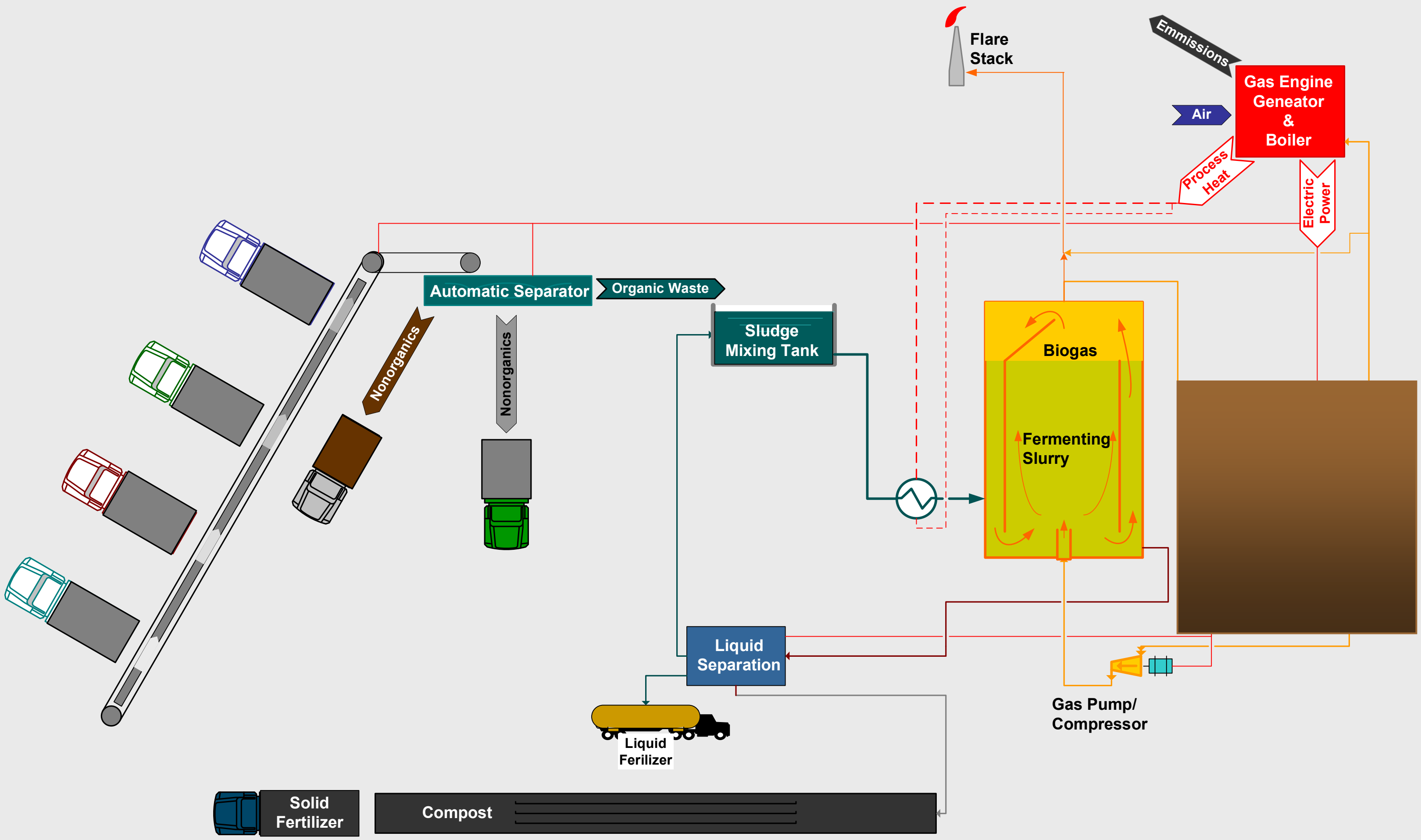
Valorga Technology



Valorga Technology

3 Biogas Storage and Treatment Unit;

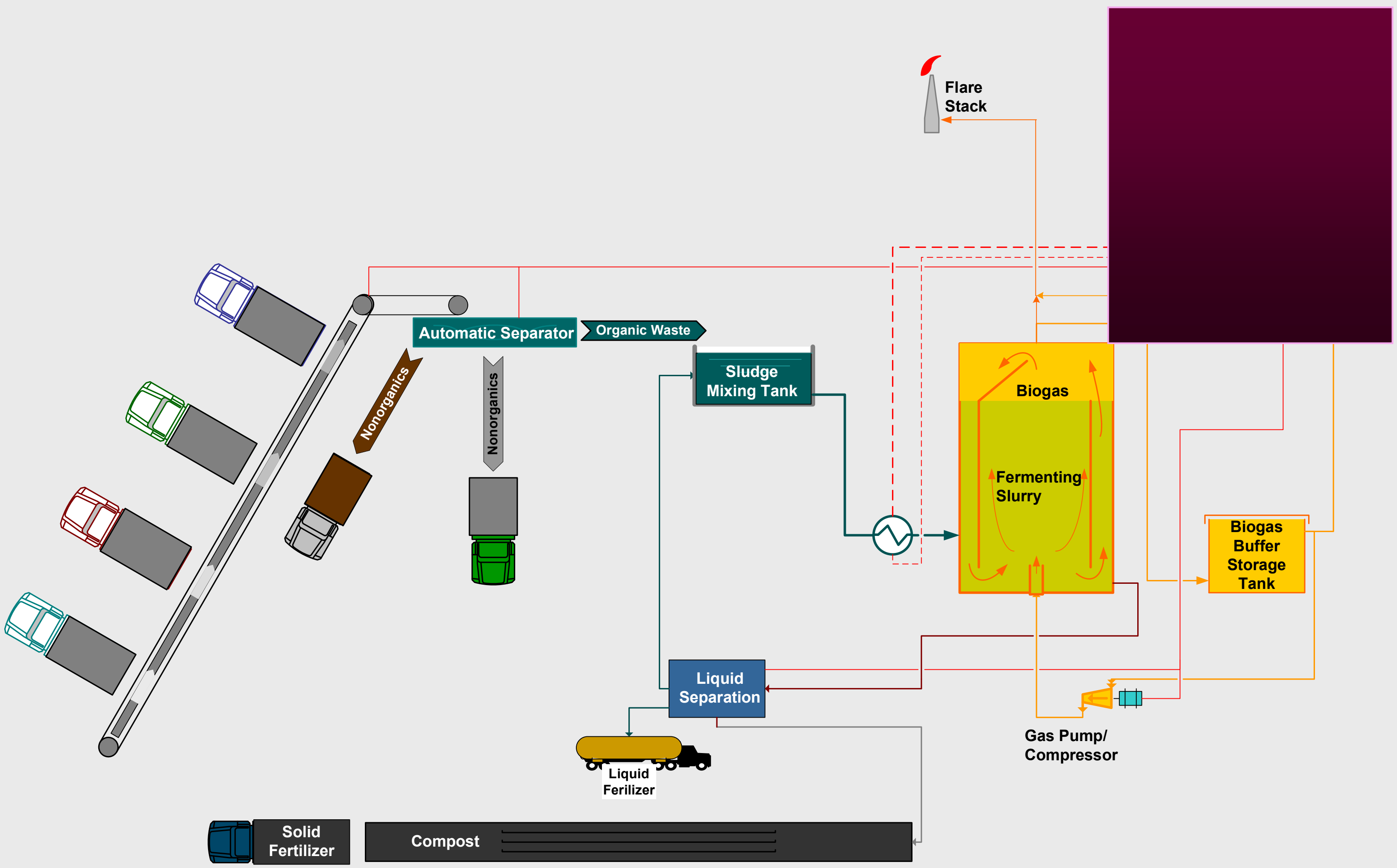
Valorga Technology



Valorga Technology

4 Biogas Utilization Unit

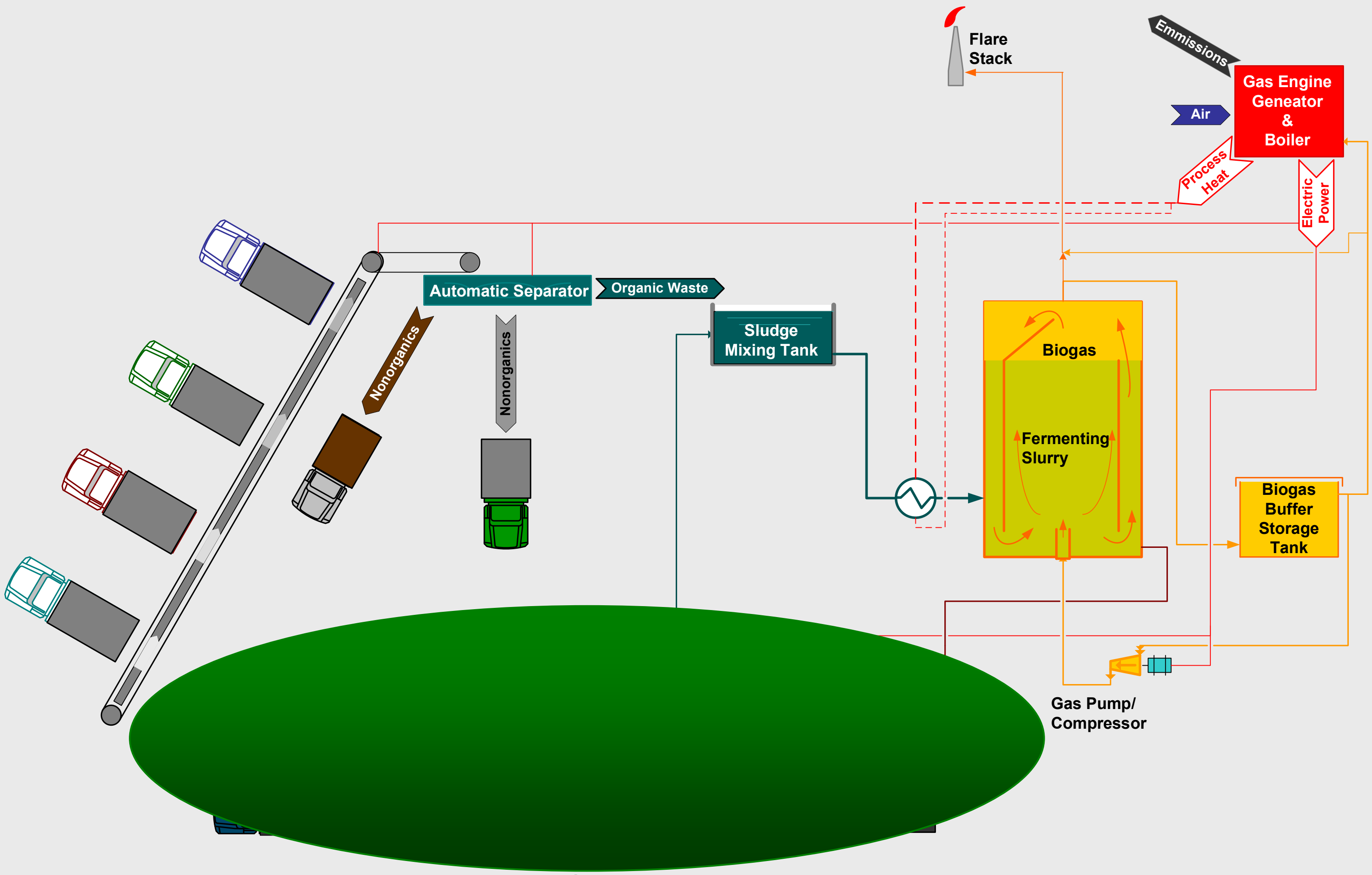
Valorga Technology



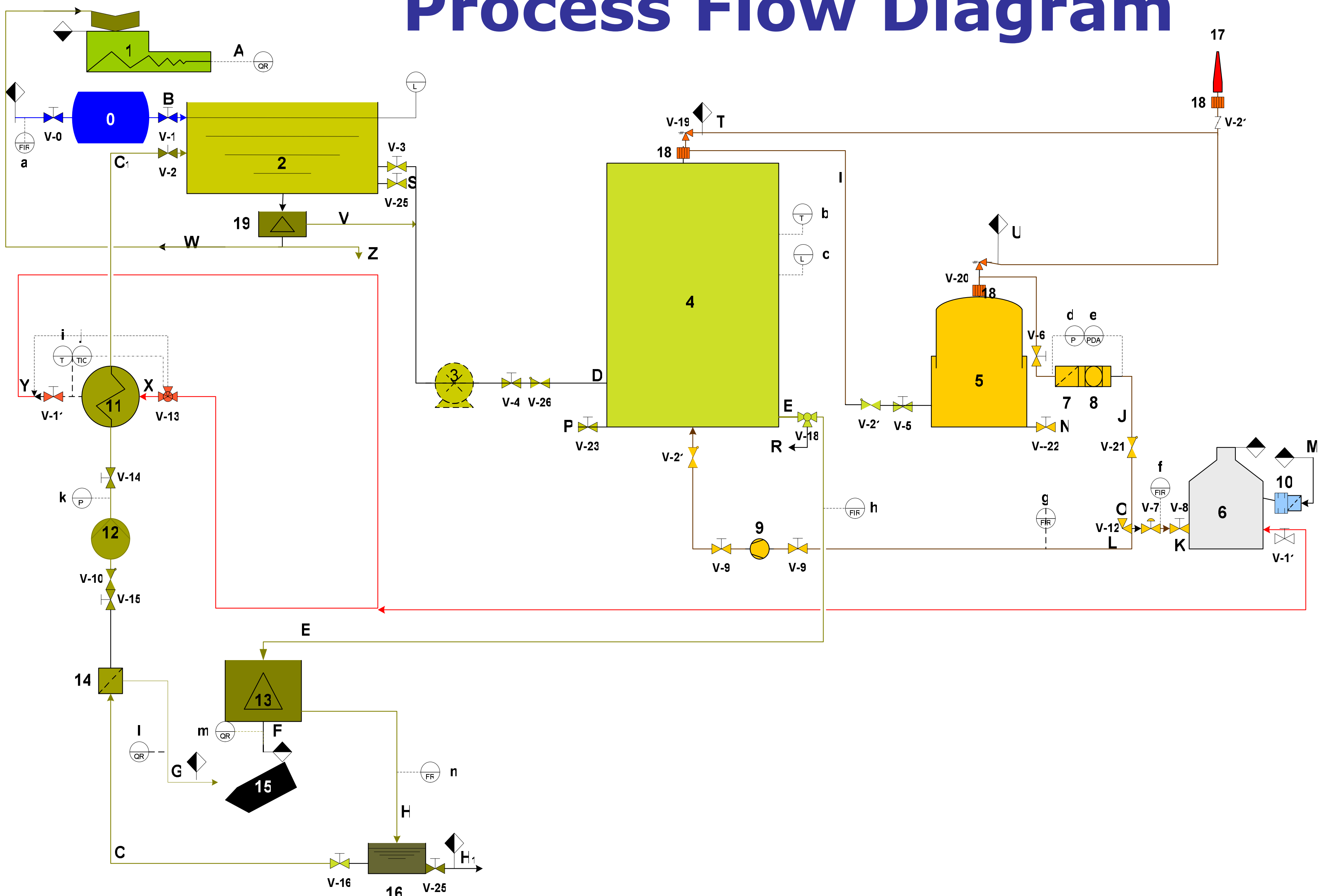
Valorga Technology

5 Compost Curing Unit

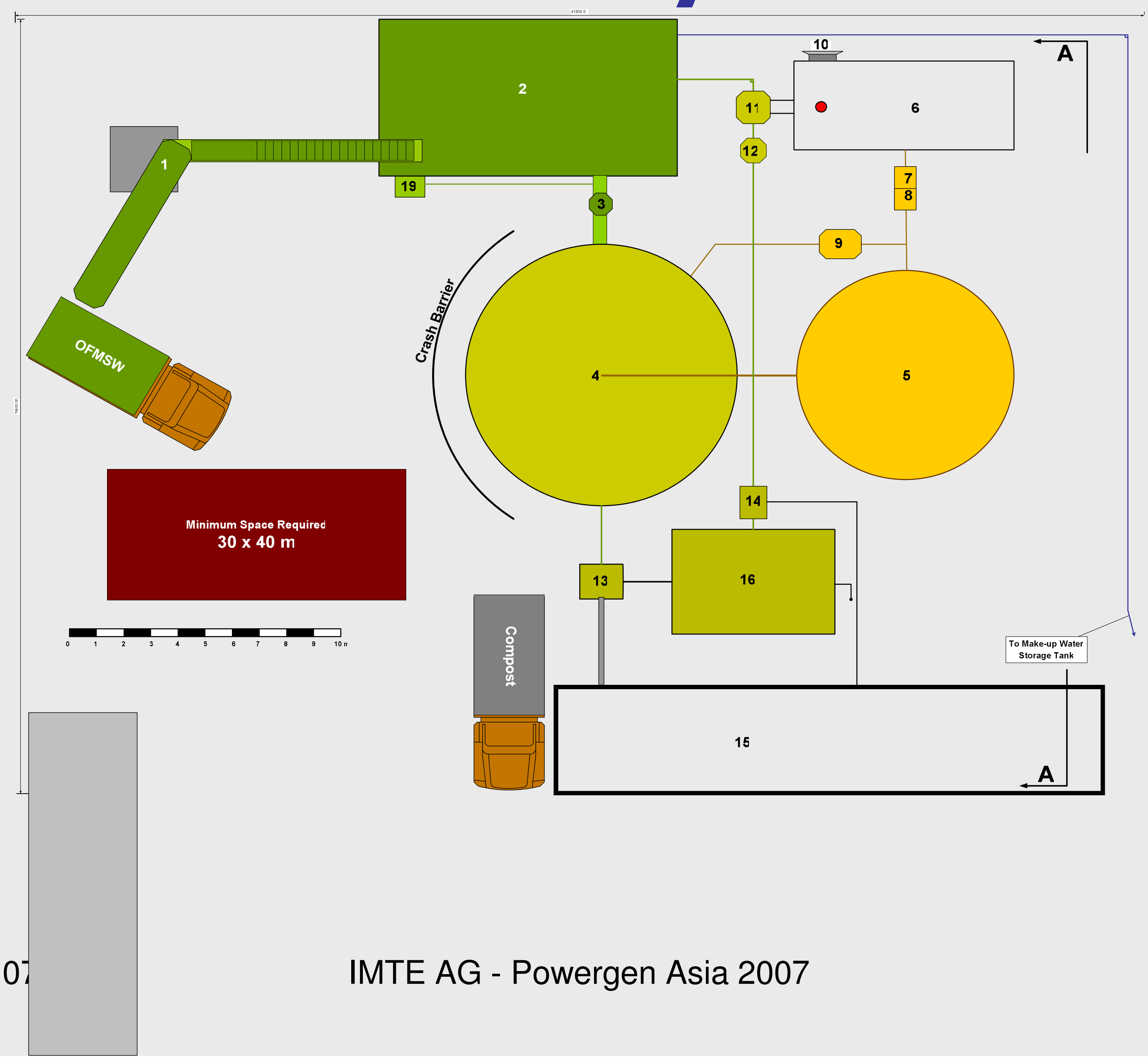
Valorga Technology



Process Flow Diagram



Plant Layout



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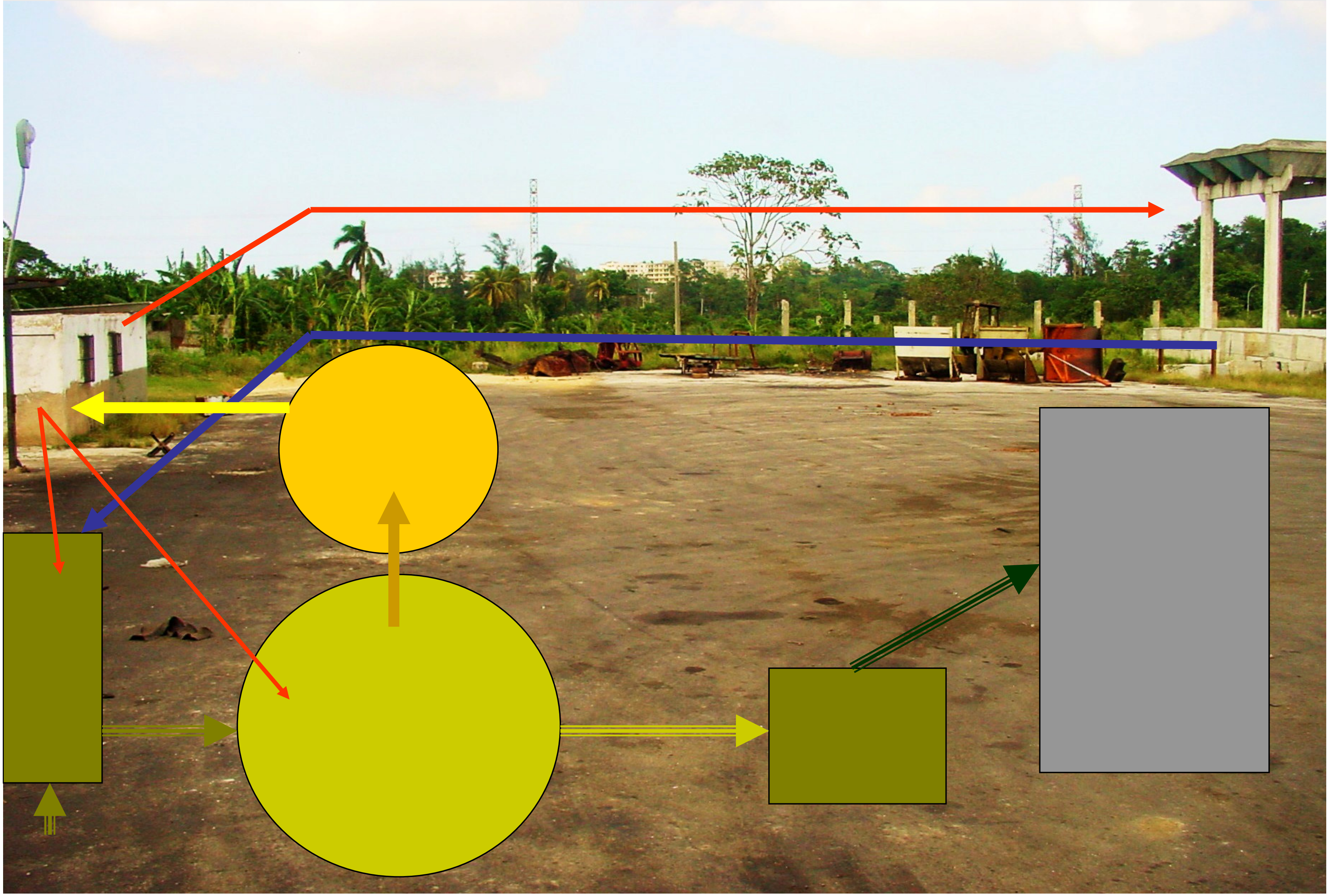
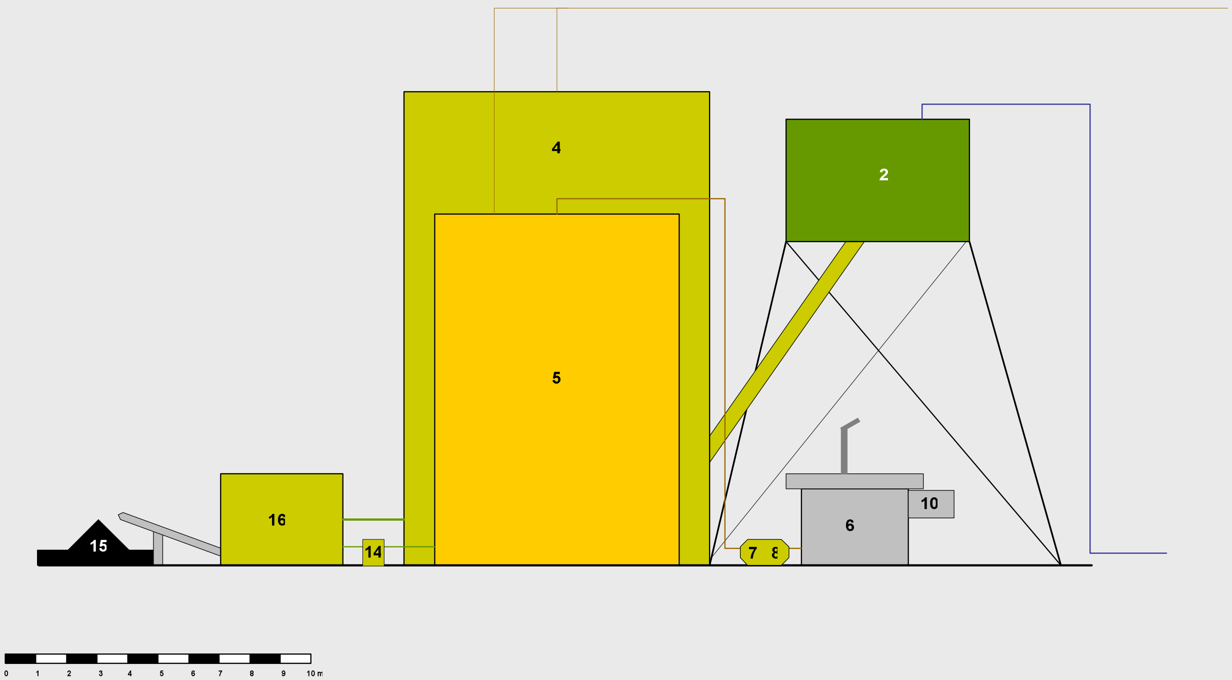


Plant Layout
Cross Section

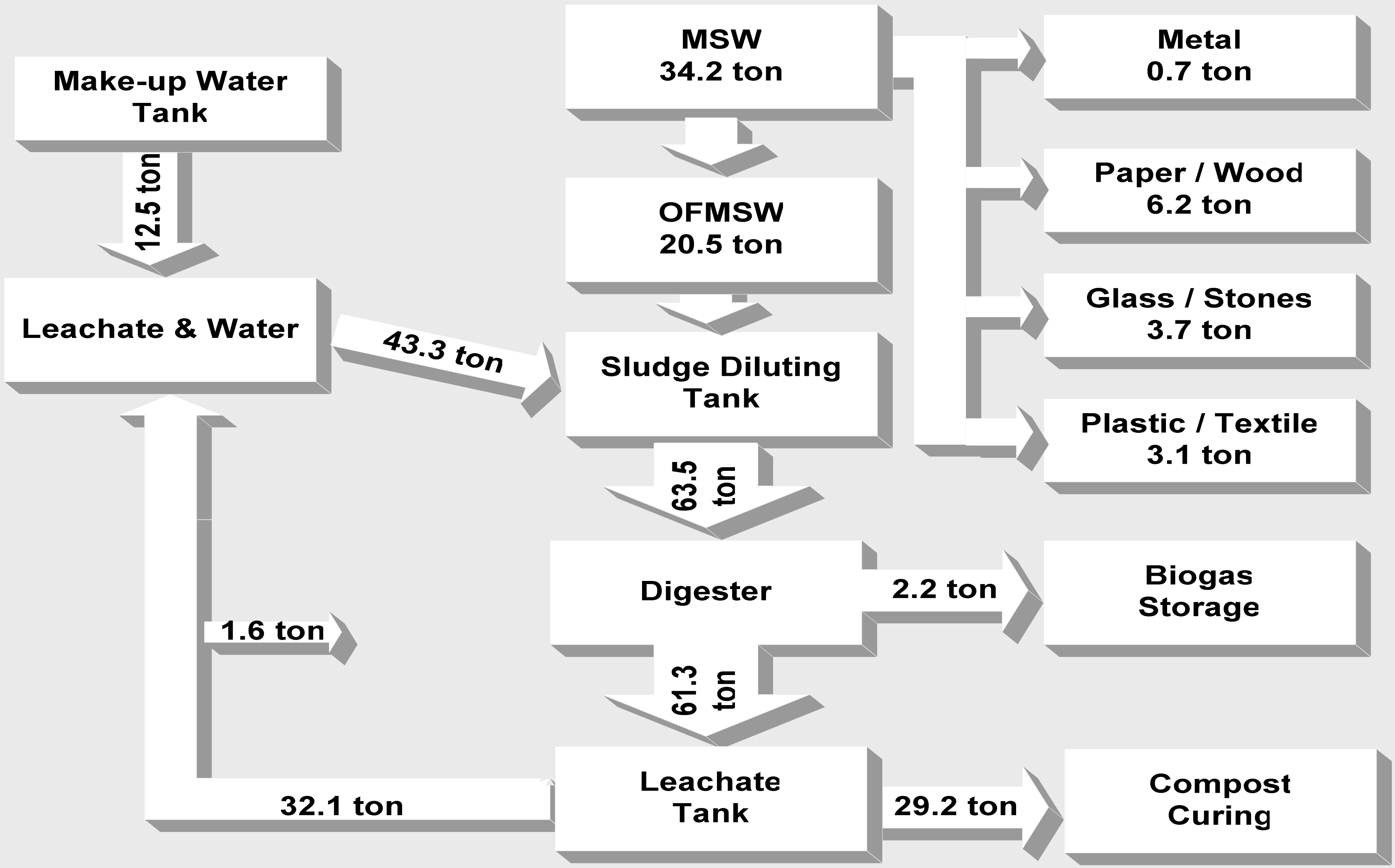


Process Parameters

Subject	Abbreviation	Unit	Range	Value Alternative 1	Value Alternative 2
Volatile Solids in OFMSW	VS	%	70-85	76	76
OFMSW (specific)	OFMSWs	ton	-	1	1
OFMSW per day	$OFMSW_D$	ton/Day	-	20.53	10.26
Make-up Water	MUW	%	60-80	65	65
Total Solids	TS	%	20-40	32	32
CH_4 Yield	Y	$Nm^3/kgVS$	0.15-0.35	0.25	0.25
CH_4 Content	C	%	55-65	60	60
CH_4 LHV	C_{LHV}	MJ/ Nm^3	35.9	35.9	35.9
Biogas LHV	B_{LHV}	MJ/ Nm^3	19.7-23.3	21.54	21.54
Hydraulic Retention Time	HRT	days	10-25	15	15
Digester Loading Rate	DLR	$kgVS/m^3/d$	10-15	13	13
Digester Volume	DV	m^3	-	1200	600
Sludge Density	ρ_{SL}	ton / m^3	0.8-1.0	0.9	0.9
Temperature	T	ºC	37-40	37	37
pH	pH	-	7-8	7.5	7.5
Anticipated Power Production	P	kW	50-300	100	50

Gas Engine-Generator Efficiency	**η**	**%**	**32-38**	**35**	**35**
Power Load Factor	**PLF**	**%**	**80-85**	**80**	**80**
Biogas Specific Production	M_{BG}	**Nm^3/tonOFMSW**	**-**	**101.33**	**101.33**
Bigas Density	ρ_{BG}	**kg/ Nm^3**	**1.1-1.25**	**1.20**	**1.20**
CH_4 Production	M_{CH4}	**Nm^3/tonOFMSW**	**-**	**60.80**	**60.80**
Energy Production	**E**	**MJ/tonOFMSW**	**-**	**2182.72**	**2182.72**
Engine Fuel Consumption	**Fc**	**Nm^3/sec**	**-**	**0.01326**	**0.00663**
Fuel Consumption per Hour	**FcH**	**Nm^3/hour**	**-**	**47.75**	**23.88**
Fuel Consumption per Day	**FcD**	**Nm^3/Day**	**-**	**1'146.04**	**573.02**
Fuel Consumption per Year	**FcY**	**Nm^3/Year**	**-**	**334'643.85**	**167'321.93**
First Digester Filling	V_{MSW}	**m^3**	**-**	**1'069.08**	**534.54**
Available Biogas Space / Digester	DV_{BG}	**m^3**	**-**	**130.92**	**65.46**
Available Biogas Space / Digester	$DV_{BG\%}$	**%**	**-**	**10.91**	**10.91**
Biogas Daily Production	**BP**	**Nm^3/Day**	**-**	**1'267.50**	**633.75**
Biogas available for Recirculation	**BDR**	**Nm^3/Day**	**-**	**121.46**	**60.73**
Biogas available for Recirculation	$BDR_{\%}$	**%**	**-**	**10.60**	**10.60**
Water Buffer Storage Tank	WB_{ST}	**m^3**	**-**	**6.0**	**3.0**
Mixing & Diluting Tank RT	DT_{RT}	**days**	**-**	**4.0**	**4.0**
Mixing & Diluting Tank Volume	**DTv**	**m^3**	**-**	**256.6**	**128.3**
Outlet Collecting Tank Volume	**CTv**	**m^3**	**-**	**64.1**	**32.1**
Biogas Buffer Tank Capacity	**BBTc**	**hours**	**-**	**12.0**	**12.0**
Biogas Buffer Tank Volume	**BBTv**	**m^3**	**-**	**573.0**	**286.5**

Process Medium Flow



Summary

- AD improves landfill gas related problems at landfills such as odours and migration of explosive vapours into the soil surrounding the landfill
- Potential landfill related emissions to air are reduced and green power is generated, off-setting the need to consume fossil fuels to provide an equivalent amount of energy
- Combustion of CH_4 contained in biogas contributes to significant reductions of GHGs emissions
- Creation of green energy from biogas makes good use of a MWS that would otherwise be dumped at landfill
- Generation of electricity provides consumers with a source of environmentally friendly green power
- Additional revenue may be generated from MSW management fees, sale of electricity and sales of compost material.

Conclusions

- **The calculated environmental performance of the Pilot Project Facility indicates that annually 280 thousands Nm^3 of CH_4 can be recovered and used for electricity generation.**
- **This corresponds to 150 tons of carbon in the form of CH_4.**
- **Considering that one ton of carbon as CH_4 is equivalent to 21 tons of carbon as CO_2 the Facility's operation avoids landfill emissions of about 3,150 tons of carbon equivalent.**

Thank you

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