CETESB
Energy From Biogas
April 23rd – 24th 2003

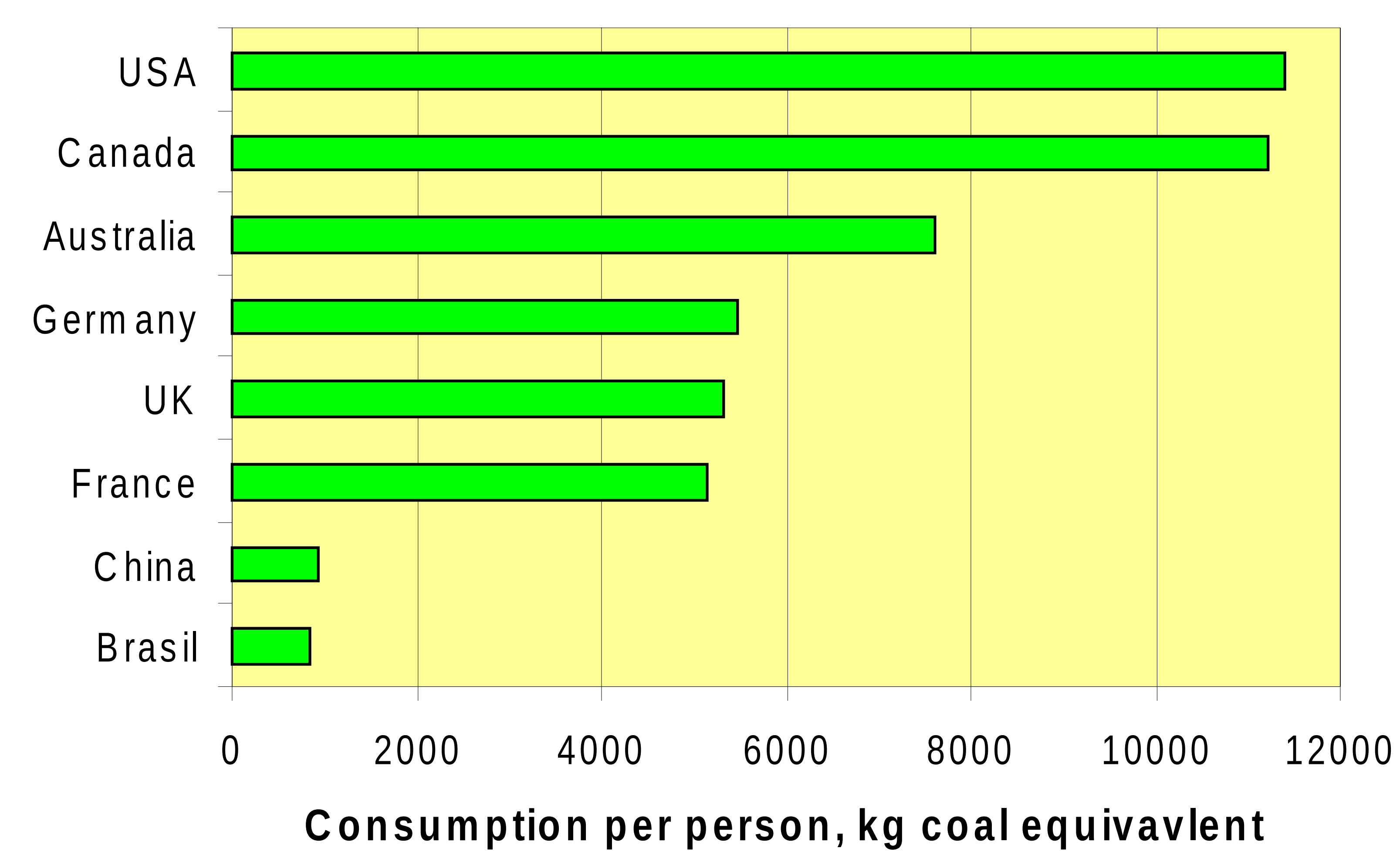
Biogas Applications

Dr Stephen P Etheridge
Environmental Biotechnology Limited

Climate Change

- Climate is changing
- Not everyone agrees it is a result of human activity
- Carbon reserves being rapidly released into the atmosphere

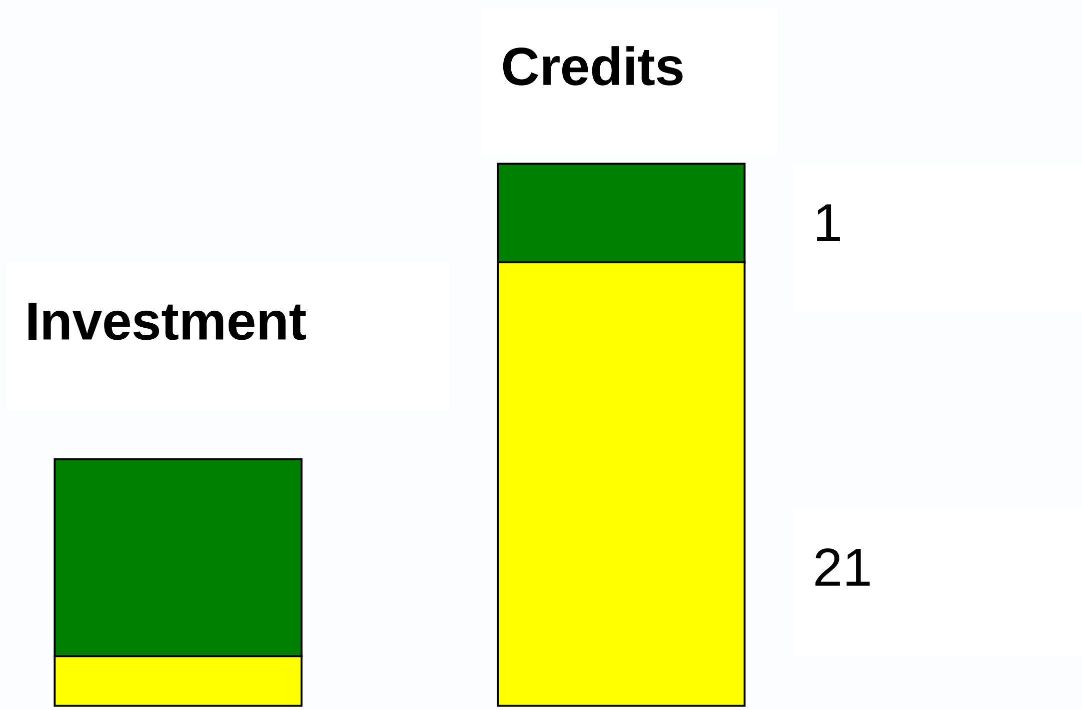
Different countries release different amounts….



Kyoto Protocol

- 10% reduction on 1990 levels
- Can mean >30% reduction on current levels in some cases
- CDM important
- Not all non Appendix 1 countries agree with trading
- Value of credits?

Mitigation and Energy



Designers Responsibilities

- Understand the process
- Learn from mistakes
- Know the waste
- UK has bitter experience

Anaerobic Treatment

Waste + Heat (35°C/55°C)

90 % COD Removal ENDOTHERMIC

Slow Growing Bugs...

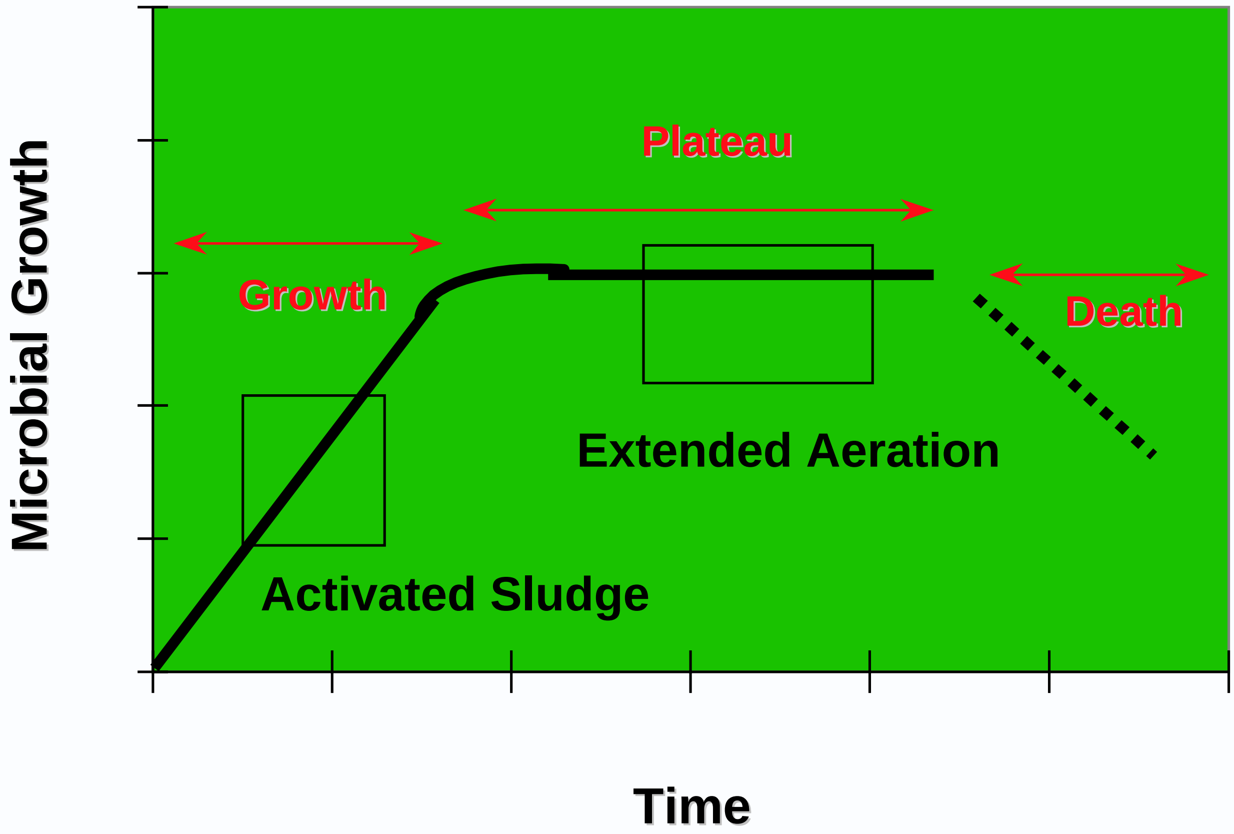
No Sludge, COD to Biogas

Low COD Effluent +

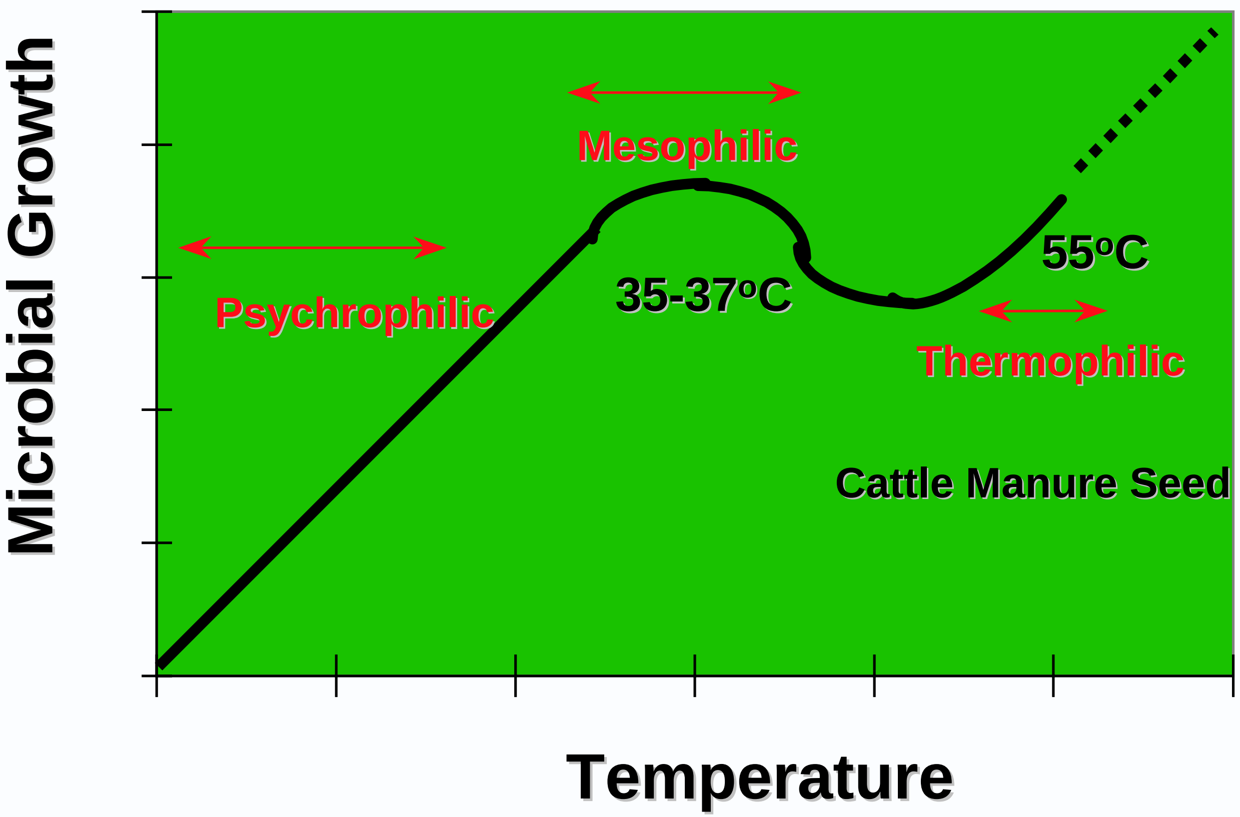
Biogas (65%CH_4 + 35% CO_2)

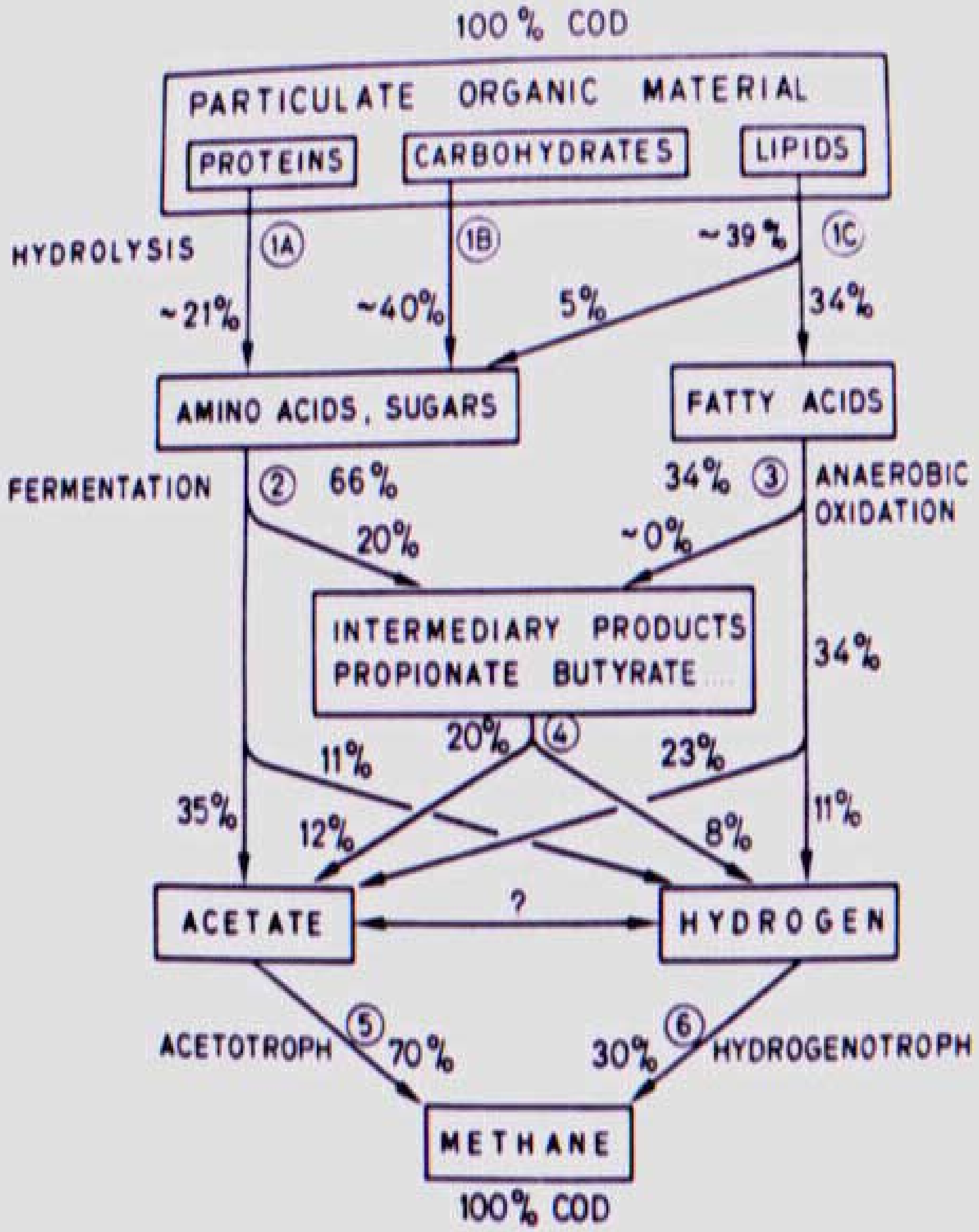
Energy Costs *Larger Reactors*

Life and Death of a Microbe



Optimum Digestion Temperatures




100% COD
PARTICULATE ORGANIC MATERIAL
PROTEINS
CARBOHYDRATES
LIPIDS
HYDROLYSIS
1A
1B
1C
~21%
~40%
5%
~39%
34%
AMINO ACIDS, SUGARS
FATTY ACIDS
FERMENTATION
2
66%
34%
3
ANAEROBIC OXIDATION
20%
~0%
INTERMEDIARY PRODUCTS
PROPIONATE BUTYRATE ....
34%
20%
4
11%
23%
35%
12%
8%
11%
ACETATE
?
HYDROGEN
ACETOTROPH
5
70%
30%
6
HYDROGENOTROPH
METHANE
100% COD

Simplified AD Process

Long Chain Organics

Acetogens ↓

Volatile Fatty Acids — VFA Test < 3,000 mg/l

Methanogens ↓

Methane + Carbon Dioxide — Methane %

What Wastes Can you Treat with AD?

- Sewage
- Animal Manures
- Industrial Effluents:
  - Food Industry
  - Paper & Pulp Industry
  - Chemical Industry
  - Pharmaceutical Wastes
  - Petrochemical
  - Steel Wastewasters
- Solid Wastes: MSW etc
- COD/N/P = 100/5/1

Digester Design

how do we realise the potential of biogas?

Microbial Growth

Monod Equation:

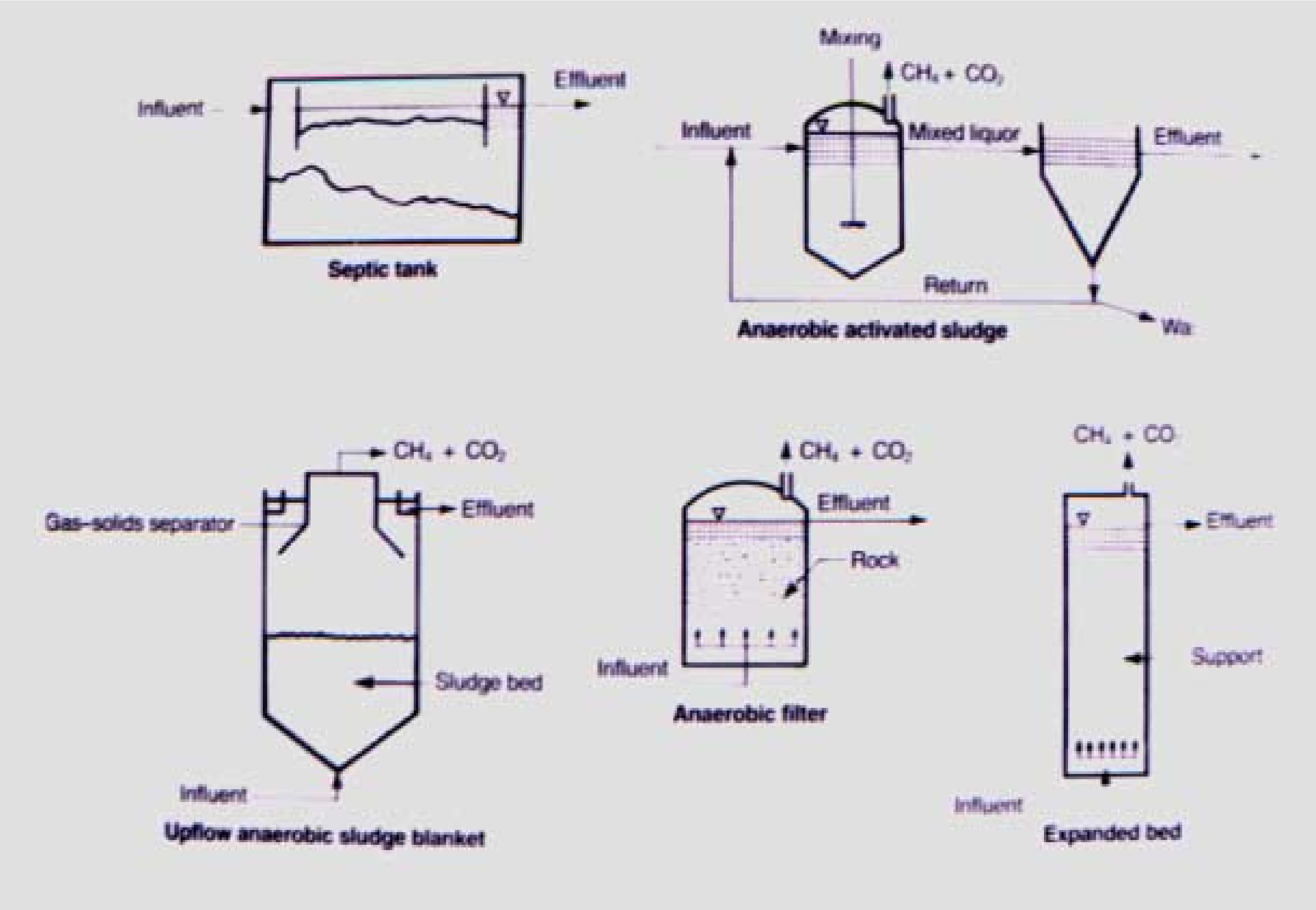
$$-\frac{dS}{dt} = \frac{kSX}{K_s + S}$$

α **Substrate**

α **Bugs**

S - substrate concentration
X - mass of microorganisms
k - maximum rate of substrate utilisation
K_s - half velocity coefficient

Digester Designs



Biomass Retention

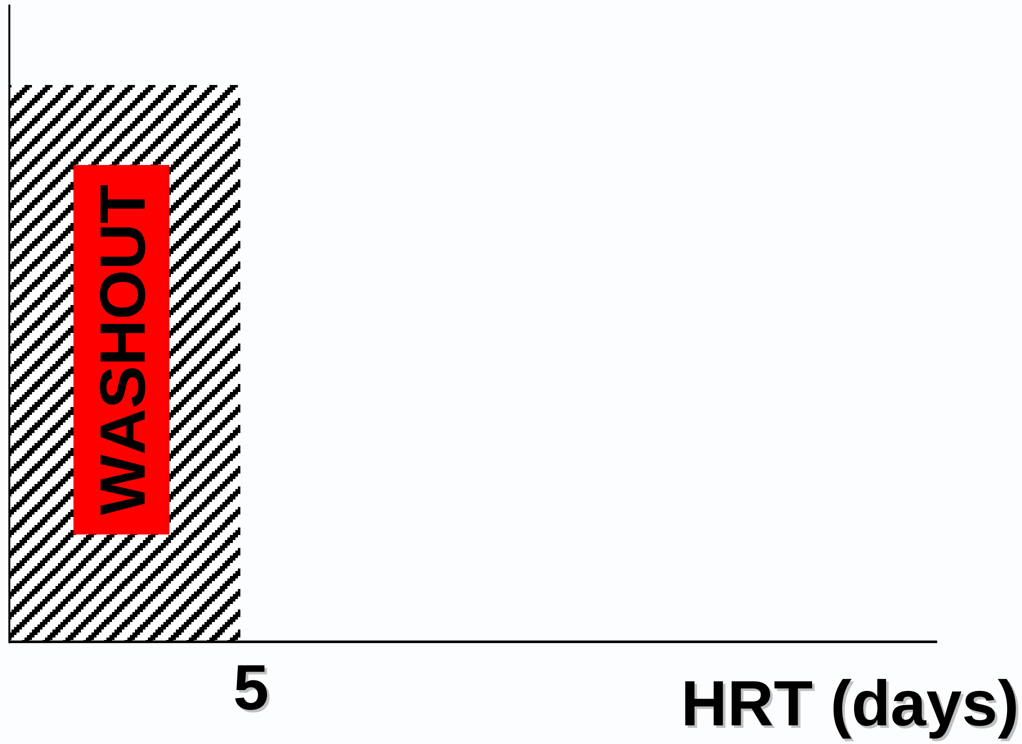
$$HRT = \frac{V}{Q}$$

HRT - Hydraulic Retention Time
V - Volume
Q - Flow Rate

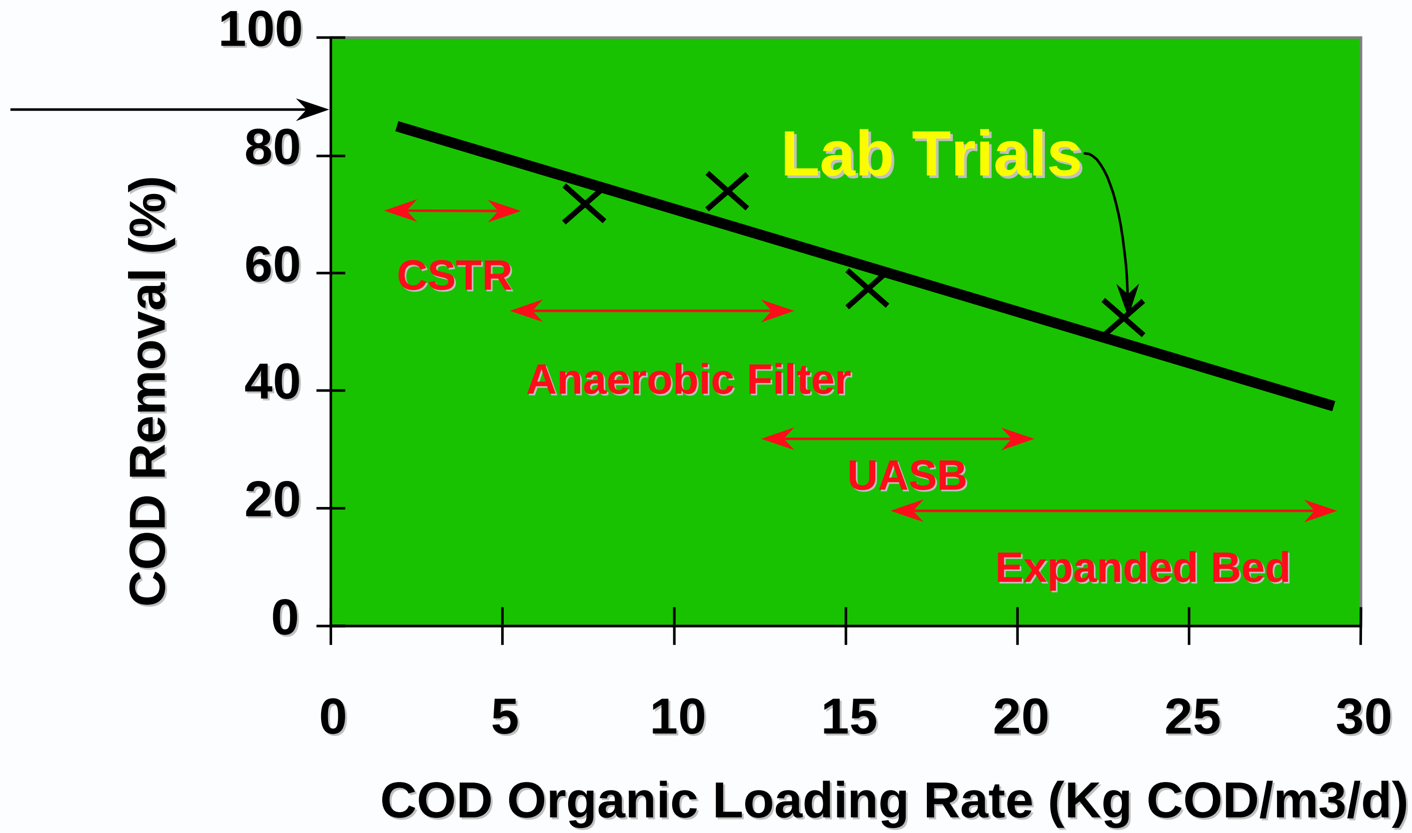
SRT - Solids Retention Time
Sr - Solids in Reactor
Se - Solids in Effluent

$$SRT = \frac{S_r}{S_e}$$

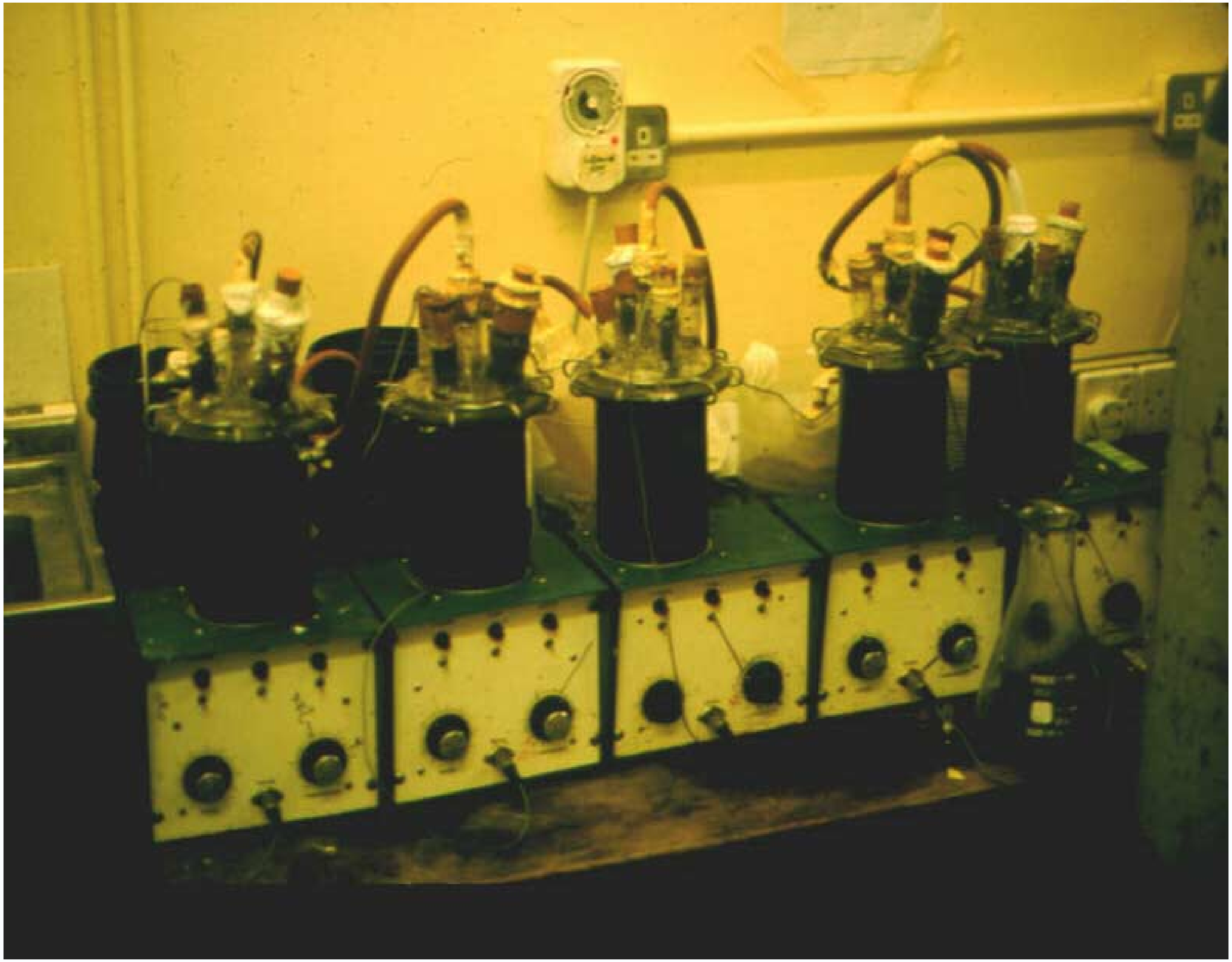
Hydraulic Limitations



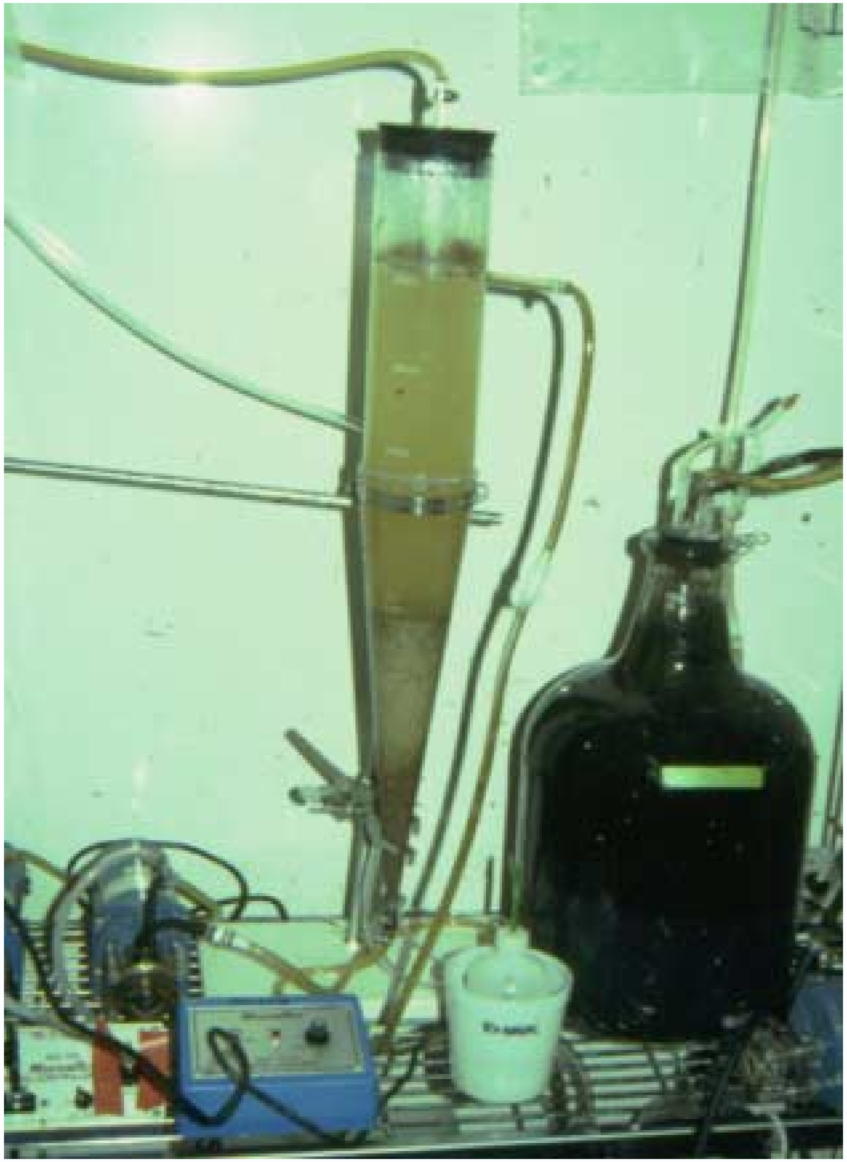
Digester Performance Curve



Laboratory Evaluation



Laboratory Evaluation



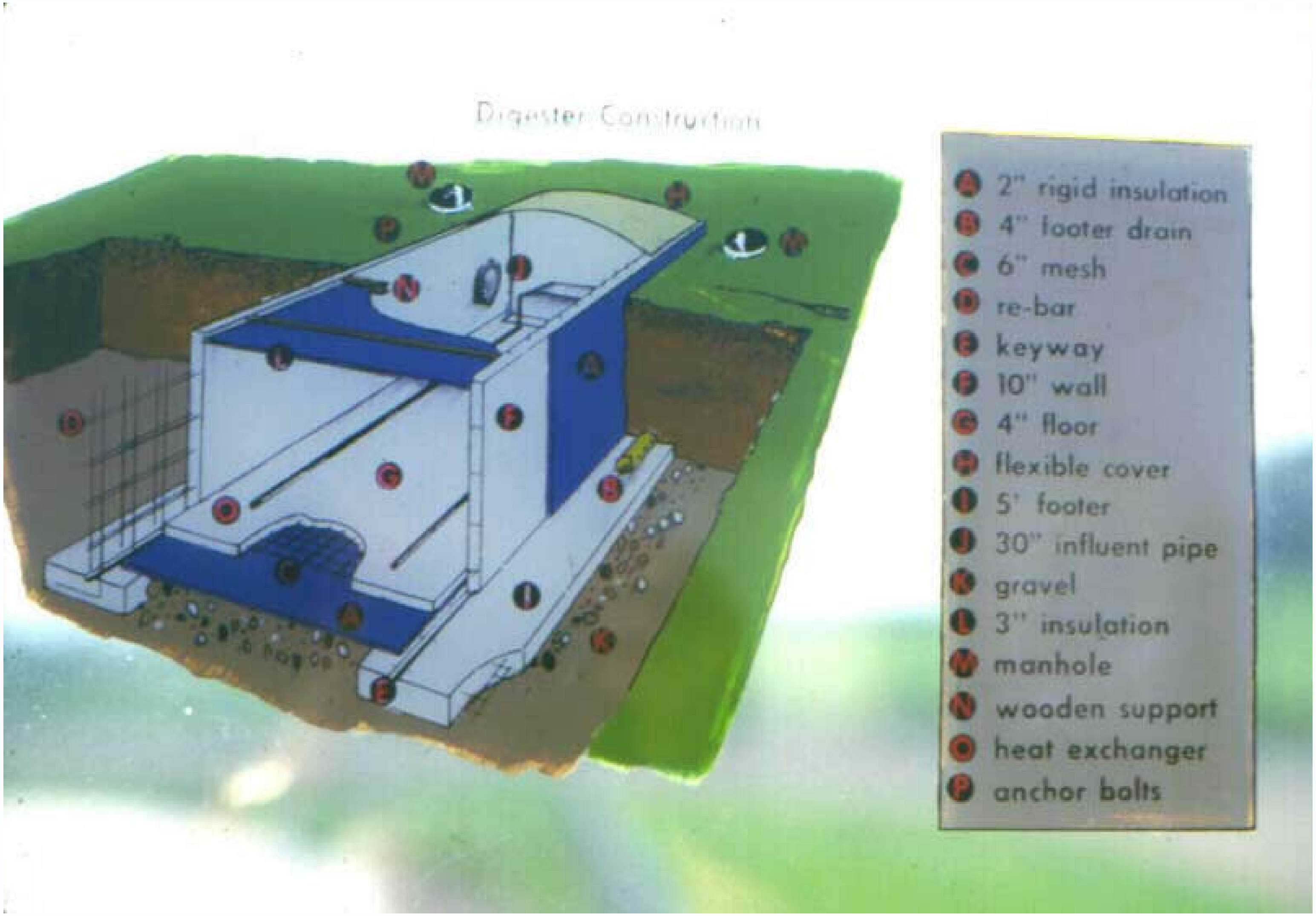
Define the Problem…
Waste Audit - Site Study

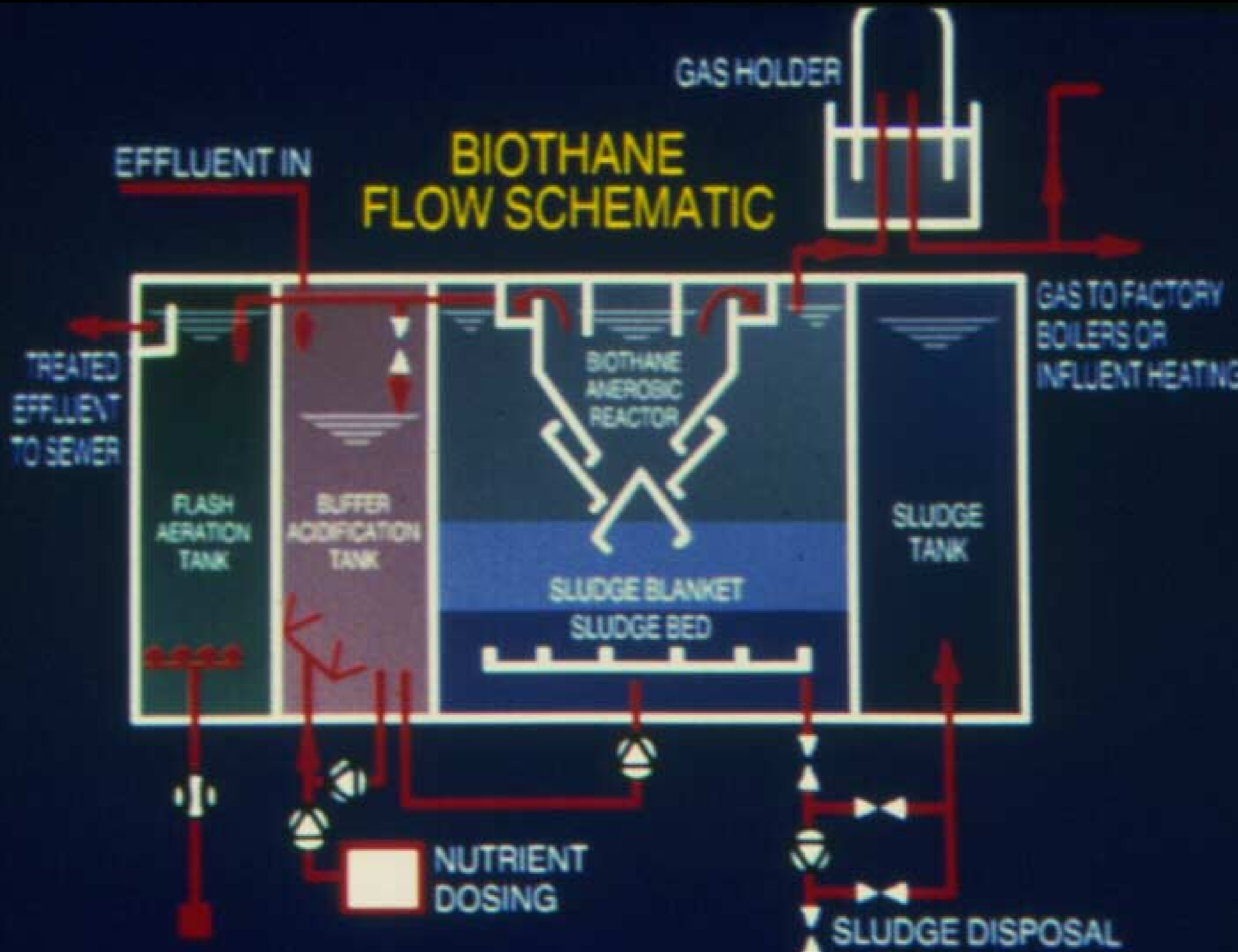
- Stream Identification
- Effluent Analysis
- Sampling
- Select the Right Process
  - Flow Proportional
  - Time Proportional
  - Spot
- Verification

Confectionery Plant

Flexible Liner Digestion Systems

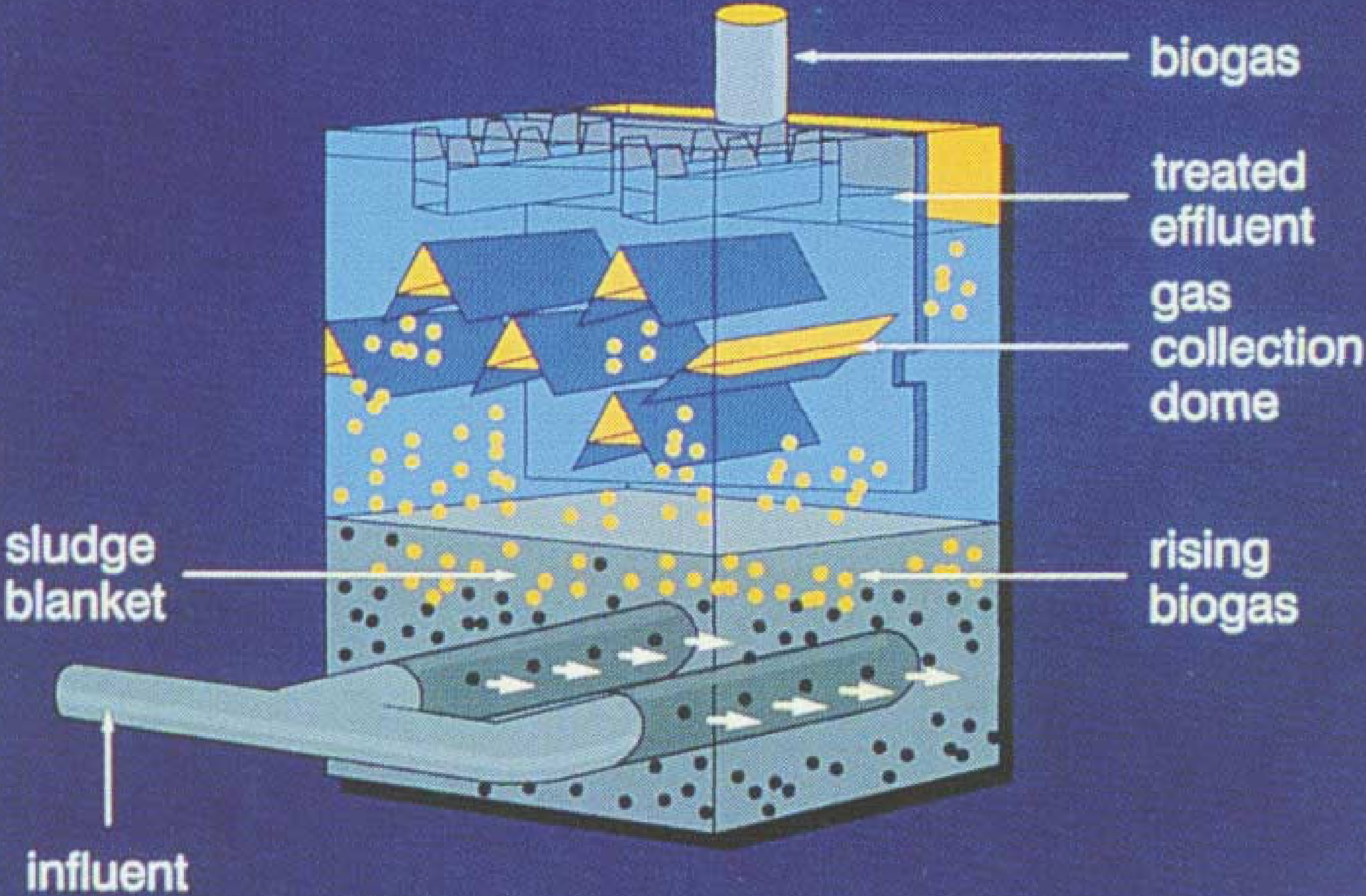
Flexible Liner Digestion Systems





BIOTHANE
FLOW SCHEMATIC
EFFLUENT IN
GAS HOLDER
GAS TO FACTORY
BOILERS OR
INFLUENT HEATING
TREATED
EFFLUENT
TO SEWER
FLASH
AERATION
TANK
BUFFER
ACIDIFICATION
TANK
BIOTHANE
ANEROBIC
REACTOR
SLUDGE BLANKET
SLUDGE BED
SLUDGE
TANK
NUTRIENT
DOSING
SLUDGE DISPOSAL

Upflow Anaerobic Sludge Blanket (UASB)



Upflow Anaerobic Sludge Blanket (UASB)

IC Reactor

Expanded Bed Digester

CASE STUDY:
Brewery and Soft Drinks Effluent

- Problem
  - Failed effluent treatment plant
  - Pressure from Water Company to reduce COD/SS
  - Very high Mogden charges
  - High variation in flow, COD, SS
- Due to
  - Plant corrosion
  - Poor design
  - Poor waste audit

Hall & Woodhouse Limited


Hall &
Woodhouse
Limited

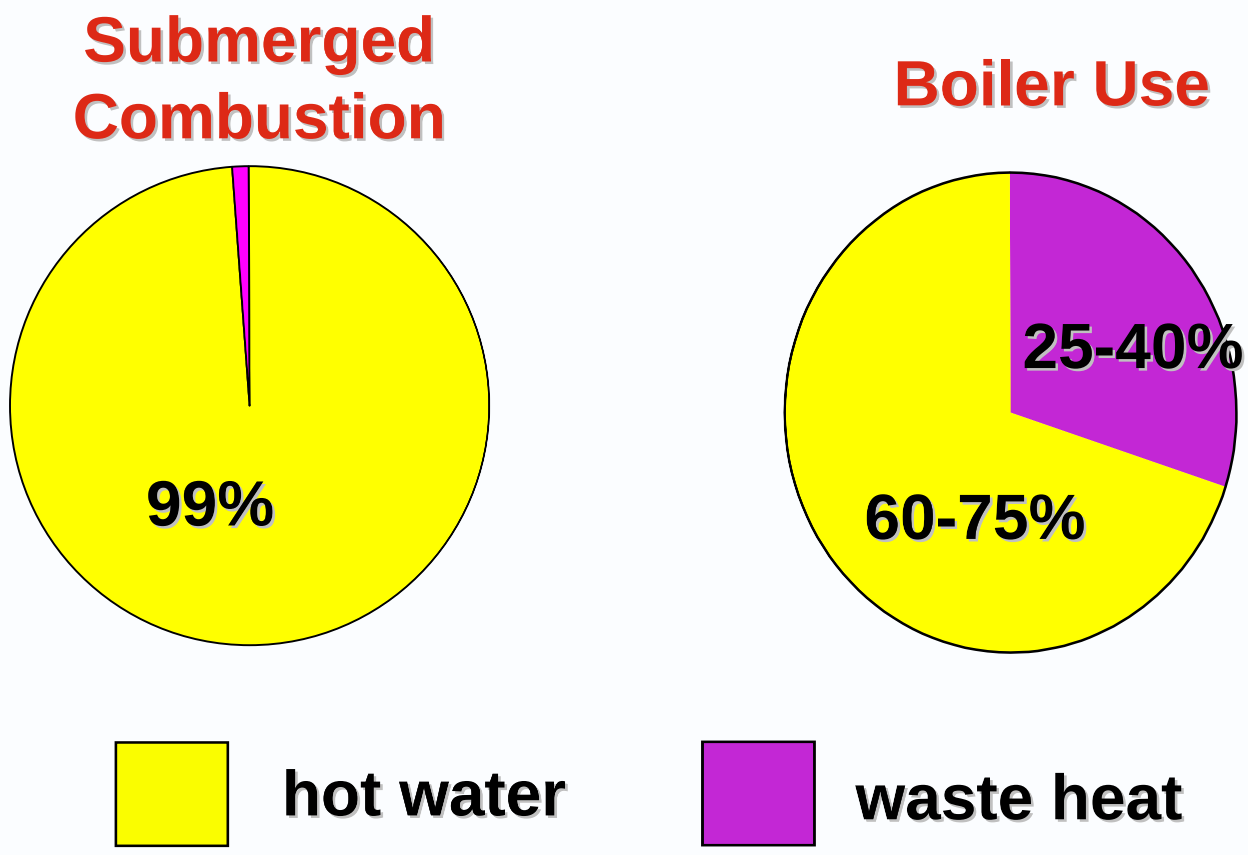
CASE STUDY: Brewery and Soft Drinks Effluent

- **Solution**
  - Comprehensive waste audit (client owned)
  - Feasibility study
    - sewer or river
    - aerobic or anaerobic
    - new technologies/grants
  - New treatment plant
  - Novel heating and mixing system
  - THERMIE Grant
  - EBL design & project management
  - Client direct purchase of all equipment

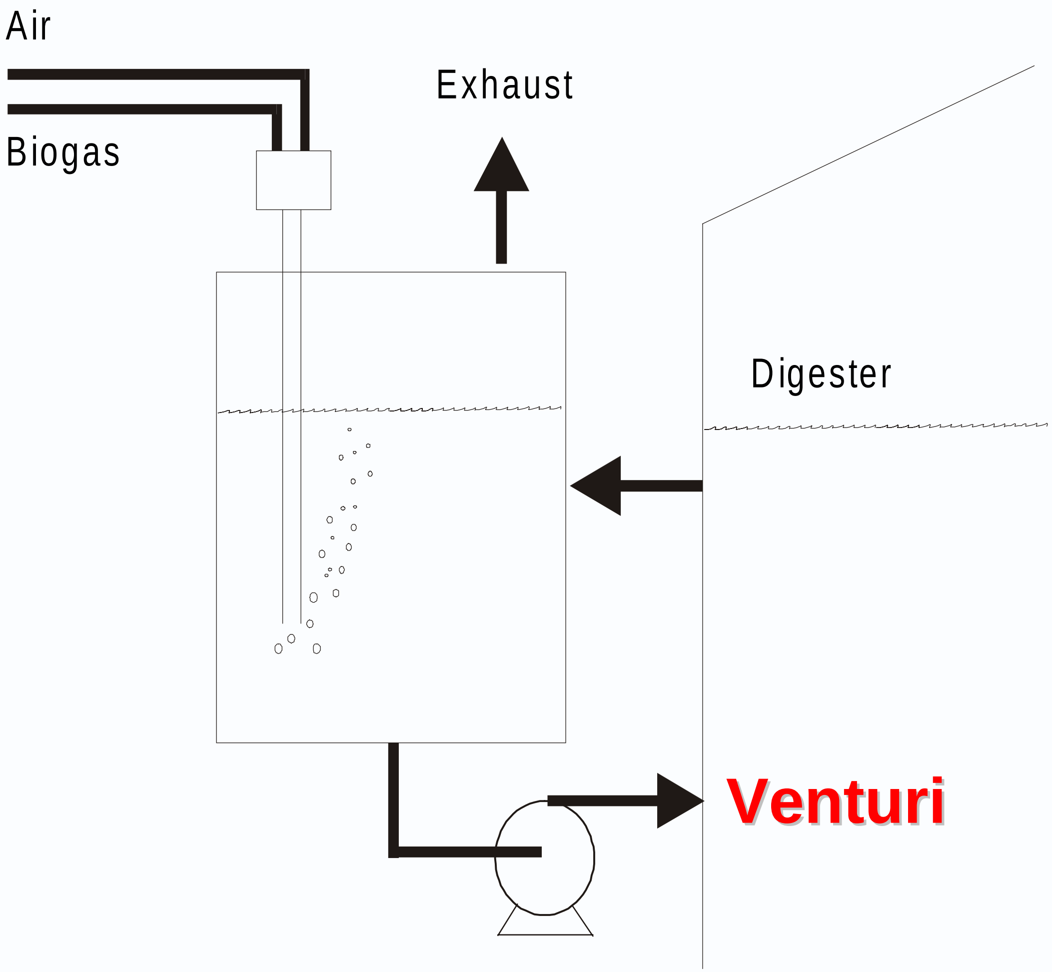
Brewery Effluent

- 3,300 m3 insulated Tank
- 600-700 m3/d, COD = 3,000-6,000 mg/l
- >98%COD Removal
- Variable Volume Reactor (Monday = 1,800 m3, Friday = 3,300m^3)
- Stirred Tank Reactor
- Heated with Submerged Combustion
- Venturi Mixing

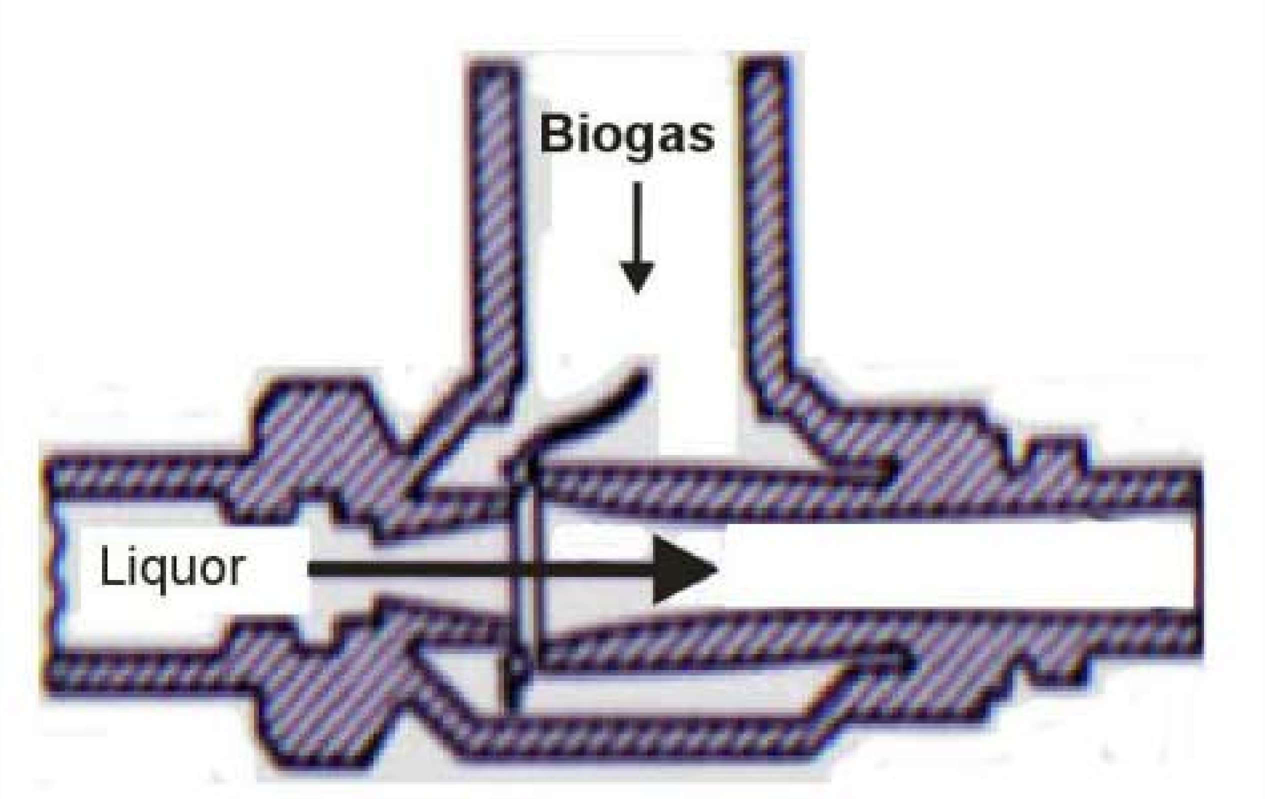
Submerged Combustion



Submerged Combustion



Venturi Mixing System



Hall & Woodhouse Limited

CASE STUDY:
Textile Industry Effluent

- Mill on Site for more than 190 Years (Part of Axminster Carpet Group)
- 140 Staff
- 2,900 tonnes Wool processed
- 2,000 tonnes Spun Yarn produced
- Lanolin wool grease and sheep dip pesticides in the fleeces

Buckfast Spinning Limited

- Buckfast Spinning has operated a flocculation effluent treatment process for 25 years
- Wool scouring and dyeing effluents combined to give overall discharge COD of 4,000 mg/l

Effluent Characteristics

- High COD (3,500 mg/l)
- Flow 420 m^3/d
- pH 6 - 8
- High Temperature Effluent (25-40ºC)
- Trace Organophosphate Pesticides
- Colour
- Grease, Dirt, Sweat Salts, Trace Sheep Dip, Oils, Dyes, Detergents

Pre-treatment of Effluent

- Effluent stored in Holding Tanks
- Pretreatment by Acid Cracking/Flocculation
- Effluent is Centrifuged and Resulting Sludge is Landfilled
- Final Effluent is Discharged to Sewer
- COD and SS Monitored
- 70% of COD is removed by Pretreatment

Problems

- £311,000 for Discharge of Effluent to Sewer in 1997 (23% increase in last two years)
- £113,000 for on- site Effluent Treatment in 1997(excl. maintenance & parts)
- Pesticide Emissions at least < 8.0 ppb
- Future Direct Toxicity Assessment
- Sensitive Location

Pilot Plant

- Two 50m^3 Reactors
- De-gas Tank prior to Discharge
- Flare/Boiler for Biogas Handling
- pH Control
- Gas Compressor for Mixing

Pilot Plant

Pilot Plant

Pilot Plant

Status and Objectives

- Biotechnology is the key to eliminating and degrading potentially harmful effluent
- Future Objectives

  - Demonstrate successful Treatment of Textile Effluent by Anaerobic Digestion
  - COD Removal (>50%)
  - Degradation of Toxic Organics and Pesticide (40-80%)
  - Colour Reduction

CASE STUDY:
Cassava Processing in Asia

- Problem
  - 6000m3/d effluent discahrged to 72 open lagoons
  - Massive methane emissions to atmosphere
  - No energy capture
- Solution
  - New Flexible Liner Digester
  - Third Party design, install, own operate
  - Natural Gas to run plant
  - Excess electricity to Grid

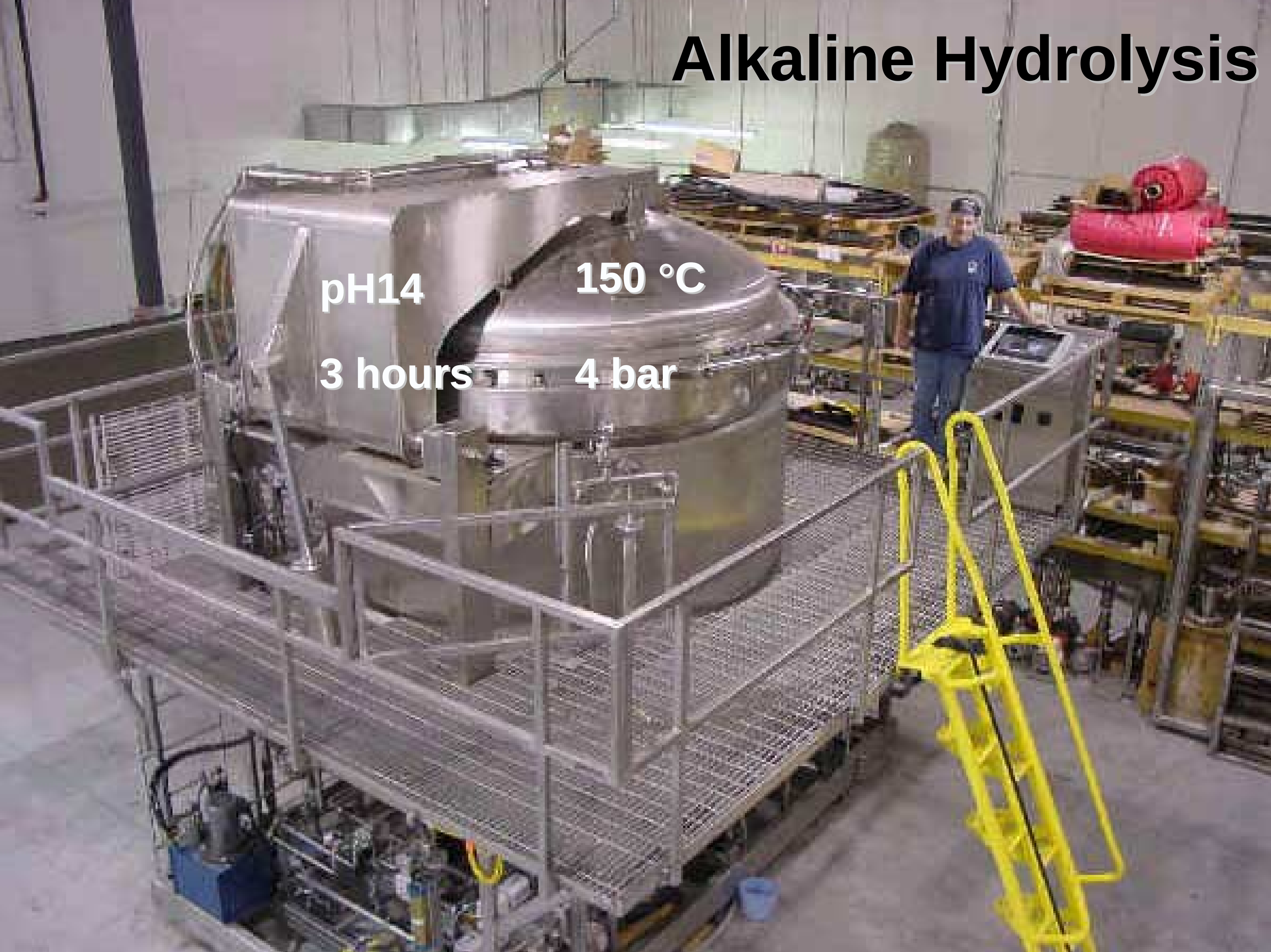
Cassava Delivery and washing

Washing and Processing

Pretreatment

Flexible Liner Digester

Digester Volume = 100,000m^3


Alkaline Hydrolysis
pH14
150 °C
3 hours
4 bar

WRE System

Centralised Digesters

- 20 years experience in Europe
- Well understood & proven in Denmark, Scandinavia & Germany
- 7 out of 20 biogas plants in Denmark take sewage sludge (1999)
- Track record of no disease spread (human or animal)
- Final Product is integrated into European “composting” networks
- Used to solve variety of waste management and public acceptance issues (e.g. Energy from Waste, landfill emissions, poor use of CHP, odours from spreading raw slurry, disposal of sewage sludge, food supply chain quality assurance)

Hashøj Biogas Plant (DK) - 140 tonnes/day – started operation 1994 (also takes Isopropanol & MSW fines from Copenhagen)

Hashøj Biogas Plant (1994)

- Digester 3000m3 operated at 37C
- 10 pig farms + 6 cattle farms feed 100t/d manure (one vacuum tanker)
- Industrial and other waste (abattoir, grease traps, fish processors etc.) 38t/d
- Pasteurisation at 70C (sterilised returned effluent)
- 2,200m3 gas storage
- Owned by cooperative, 17 members all stakeholders
- Electricity and hot water to two communities (38% of needs)

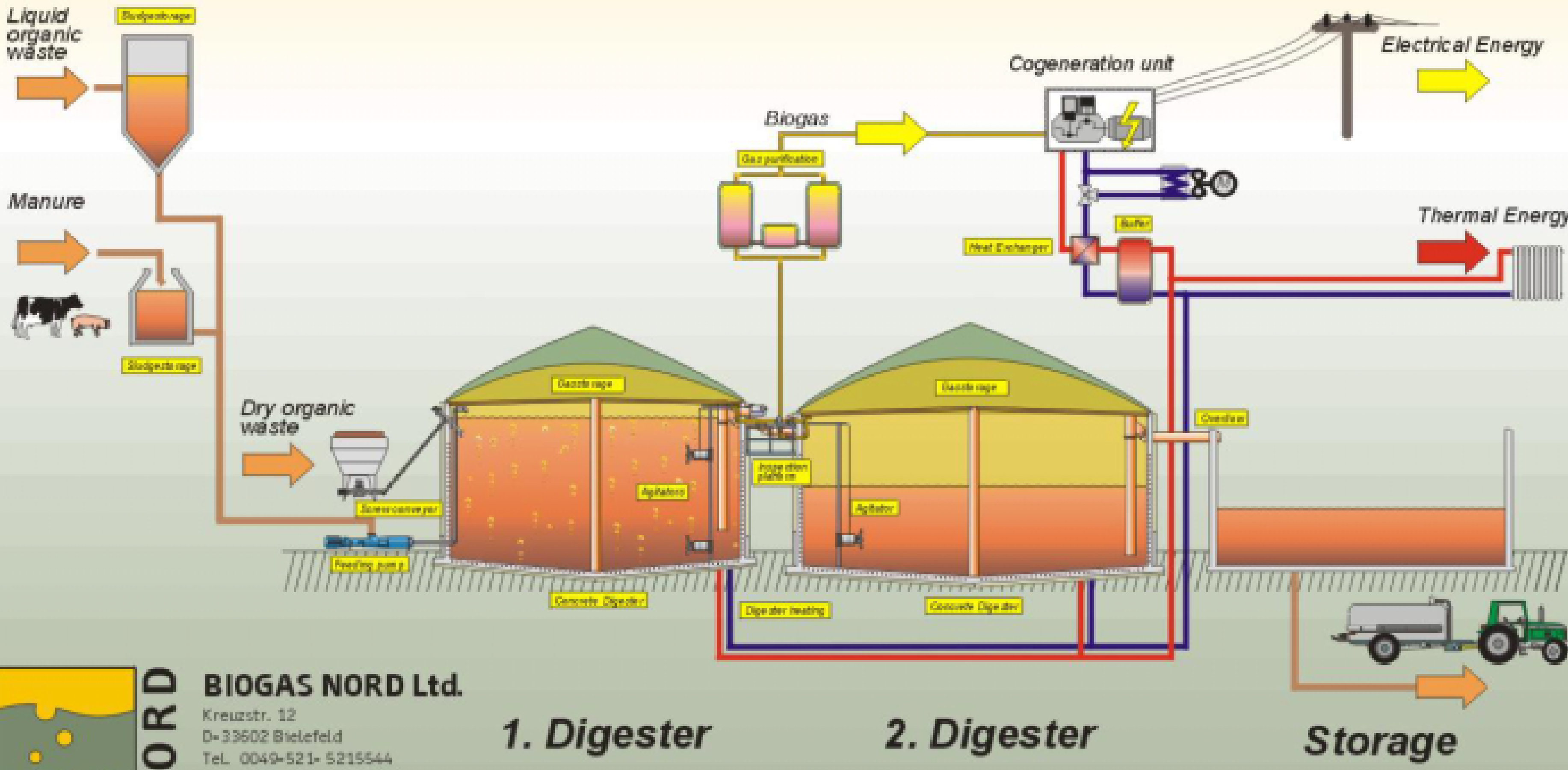
Kristianstad Biogas Plant (S) - 200 tonnes/day
- started operation 1996
(takes source separated kitchen wastes, manures)

Loick Digester

Loick Digester (2001)

- Digester 970m3 operated at 38C
- 35t/d @ 14% TS biomass from 700pigs, grease traps, food processing wastes, corn and rye silage
- 25-30 days HRT with 75% organic removal efficiency
- 2,640m3/d biogas to 249kWe CHP

Biogas system by Biogas Nord Ltd.



BIOGAS NORD Ltd.
Kreuzstr. 12
D-33602 Bielefeld
Tel. 0049-521-5215544
Fax. 0049-521-5215548
info@biogas-nord.de

© BIOGAS NORD Germany

Witte Digester (1998)

Witte Digester (1998)

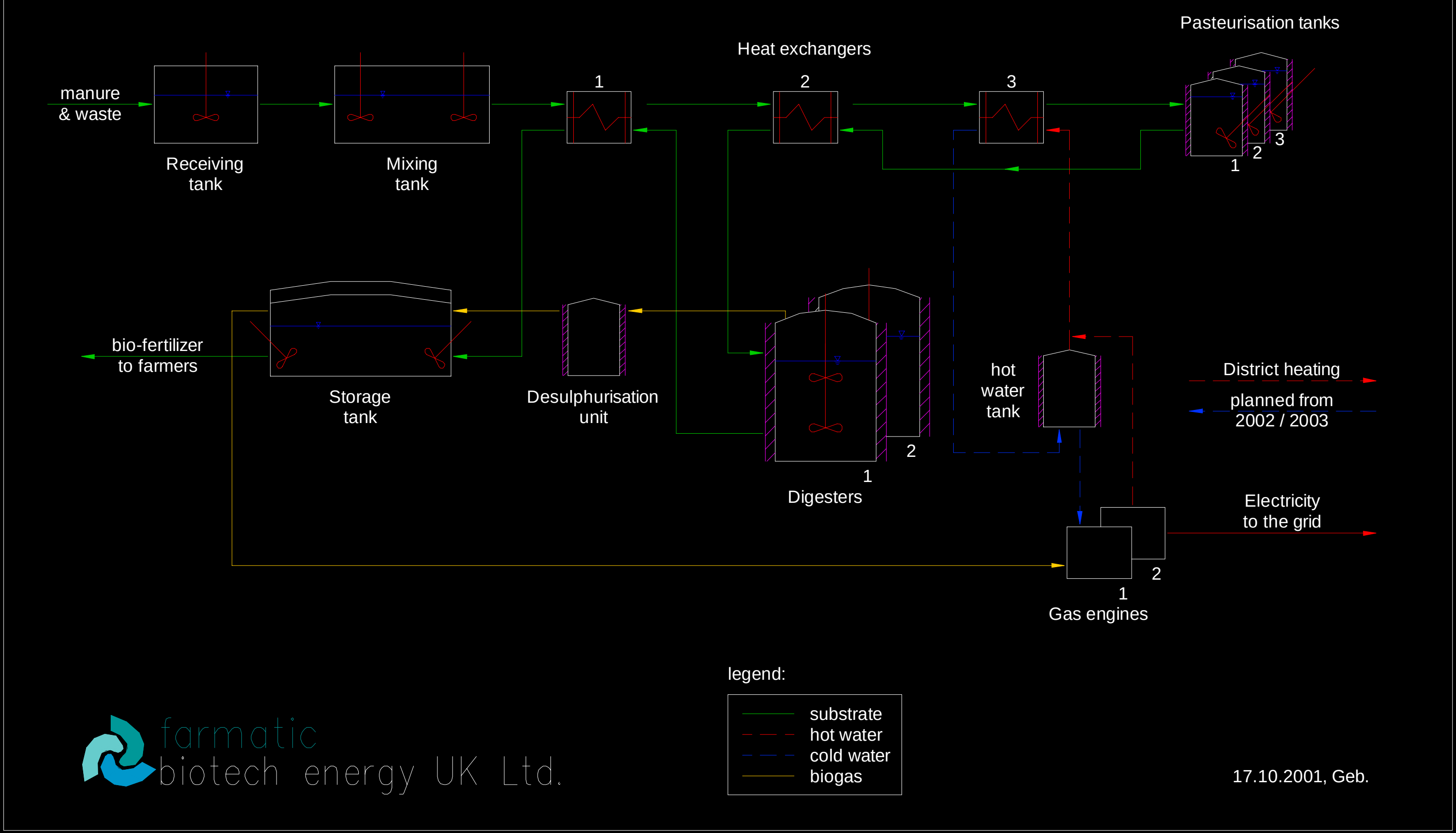
- Digester 1206m3 operated at 42C
- 16t/d @ 20% TS biomass from 80 cows, 1,100 turkeys, food processing wastes, fat , grease traps, vegetables
- 60 days HRT
- 2,000m3/d biogas to 3 x 110kWe CHP sets
- US$ 600,000 cost with 25% grant
- Revenue is US$12,000/month electric and US$1,000 fertiliser sales
- 7 year payback quoted

Holsworthy Plant, Devon

Holsworthy Biogas Company

- 146,000 tonne/y of cattle, pig & poultry manure and food waste
- Manure from 30 farmers within approx. 5 miles radius
- Pasteurisation at 70°C for one hour
- Digestion (37°C) for 20 days HRT
- Gas production: 6 million m^3 biogas (equivalent to 39m kWh)
- CHP provides on-site heat for treatment requirements
- Continual N, P & K monitoring for bio-fertiliser taken to supplying farmers

HOLSWORTHY BIOGAS - Flow sheet



Reception Hall

The Process

- Totally enclosed (& pressurised) system after unloading
- Only manually controlled at point of ‘reception pit’ to ensure right mixture goes into ‘mixing tank’ via chopper pumps
- Automatic return (re-start) if parameters of ‘pasteurisation unit’ not reached
- Farmers usually operate 3 week no grazing system
- Constant Monitoring

Tankered Effluent

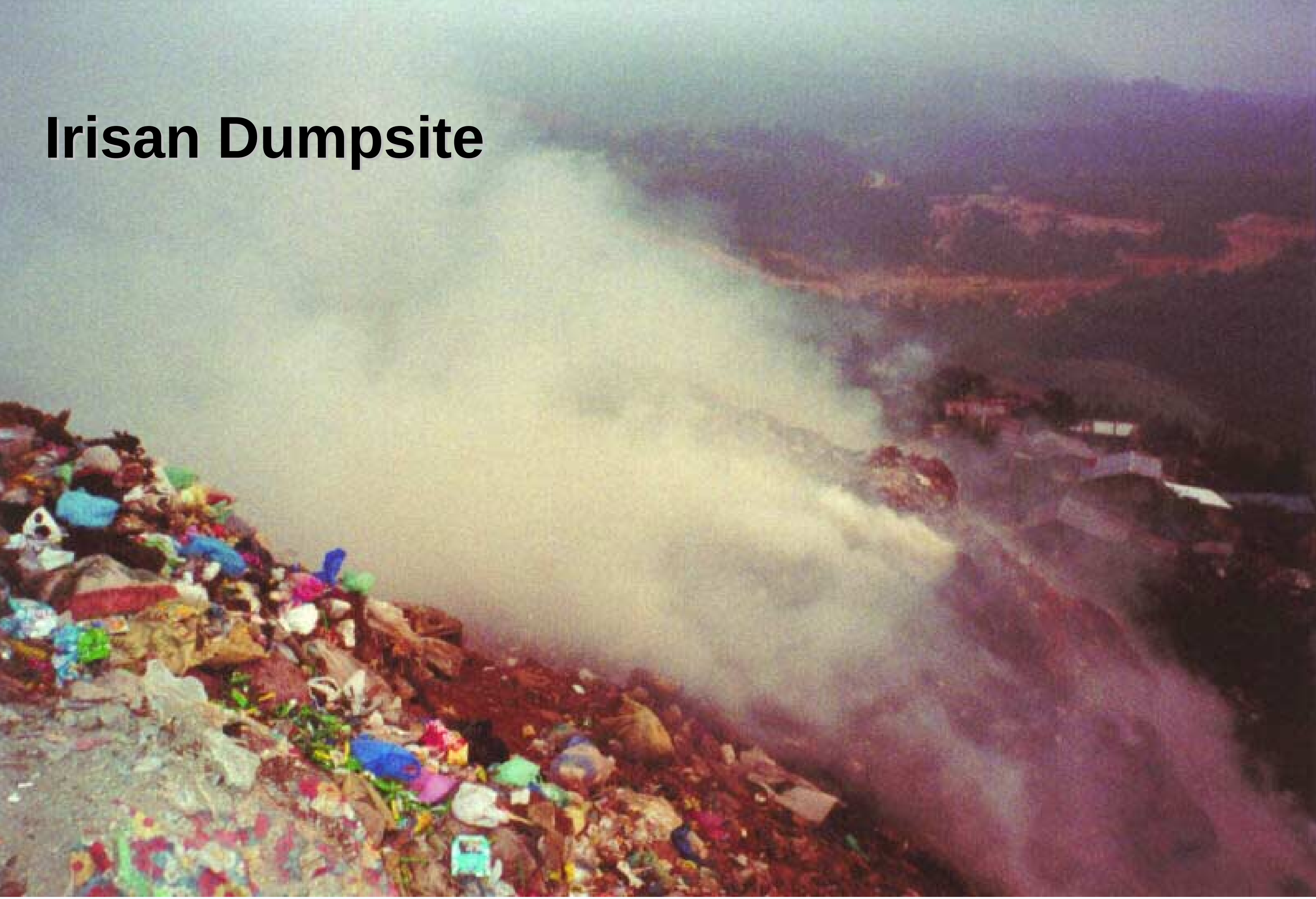
Barriers to Co-Digestion in the UK

- **Complexity of legislation increasing**
- **Limited understanding by Regulators of relatively new concept**
- **Increasing requirements for involvement with farmers and monitoring of spreading practices**
- **UK has narrow focus on “composting” industry – poor awareness**
- **Physical contamination problems when using source separated kitchen wastes (MSW)**
- **Classification of what is a “waste” and when does it become a product**

CASE STUDY: Baguio

Feasibility Study Funded by the UK Foreign & Commonwealth Office (FCO)

- Waste Study
- Site Review
  - Characterisation of Benefits
  - Collection
  - Impact on Local Community
- Design Options
- Selection, Costing and Funding


Irisan Dumpsite

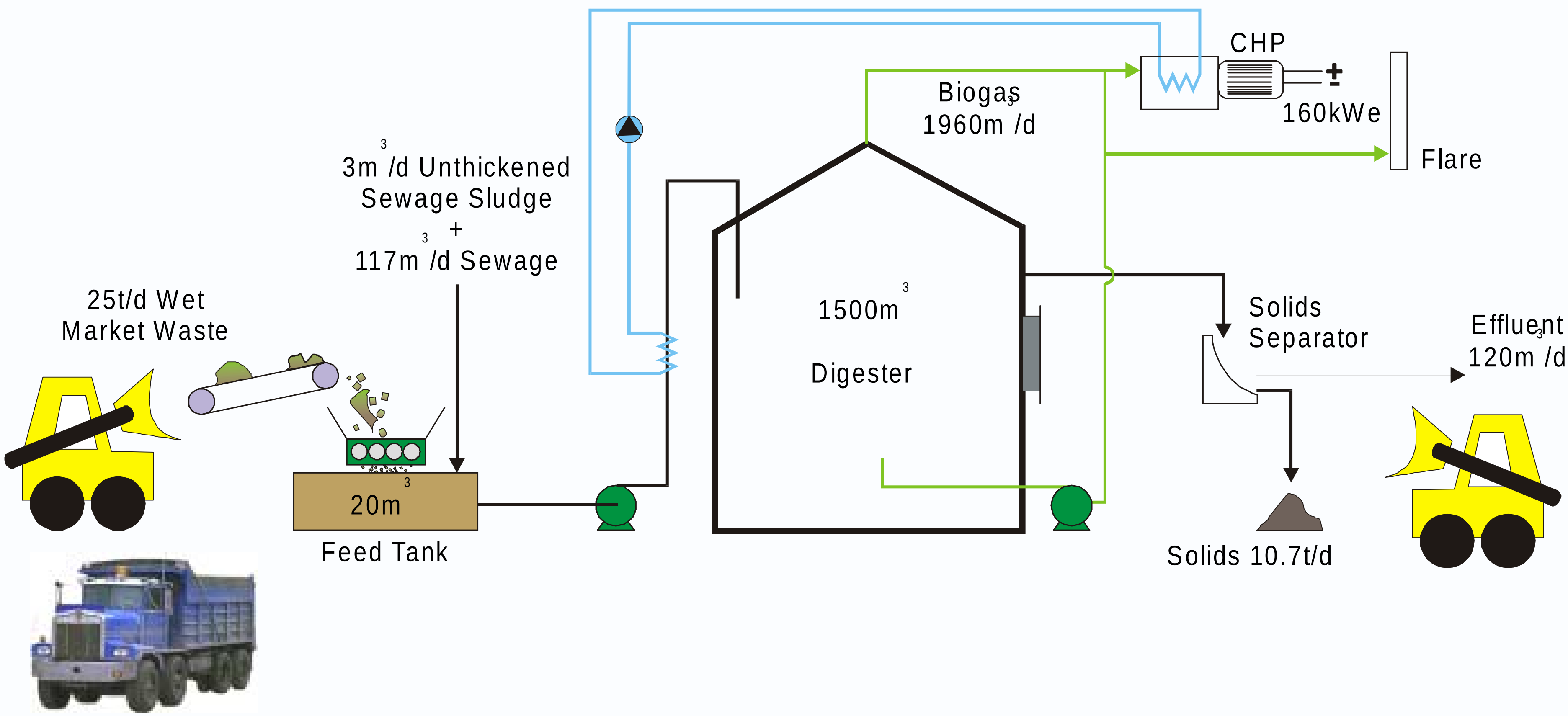

BAGUIO
CITY MAYOR
SOLID WASTE MANAGEMENT PROGRAM
OFFICE OF THE
SERVICES
OFFICER

Waste Sampling

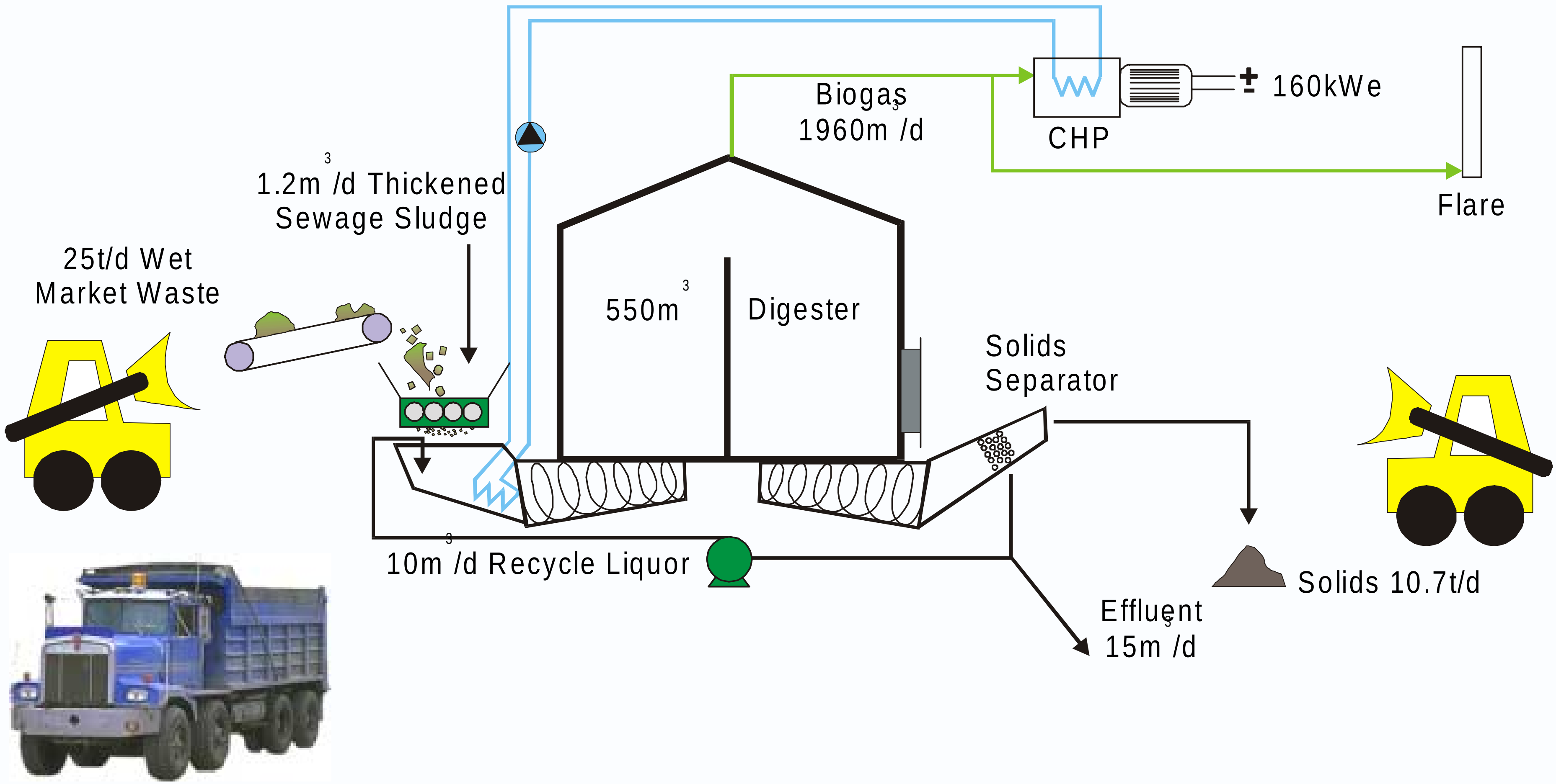
Waste Characteristics

Waste Category	*White Truck(kg)*	*Yellow Truck (kg)*
Paper	37	146
Plastic	53	479
Rubber/Leather	0	0
Vegetable/Organic Waste	4,564	1,193
Food Waste	0	0
Glass	14	2
Metal/Tin Cans	8	12
Textile	4	0
Inert	0	0
Wood	16	435
Special Waste/Fish & Meat Waste	0	20
Total	**4,696**	**2,287**
Bulk Density	470 kg/m3	229 kg/m3

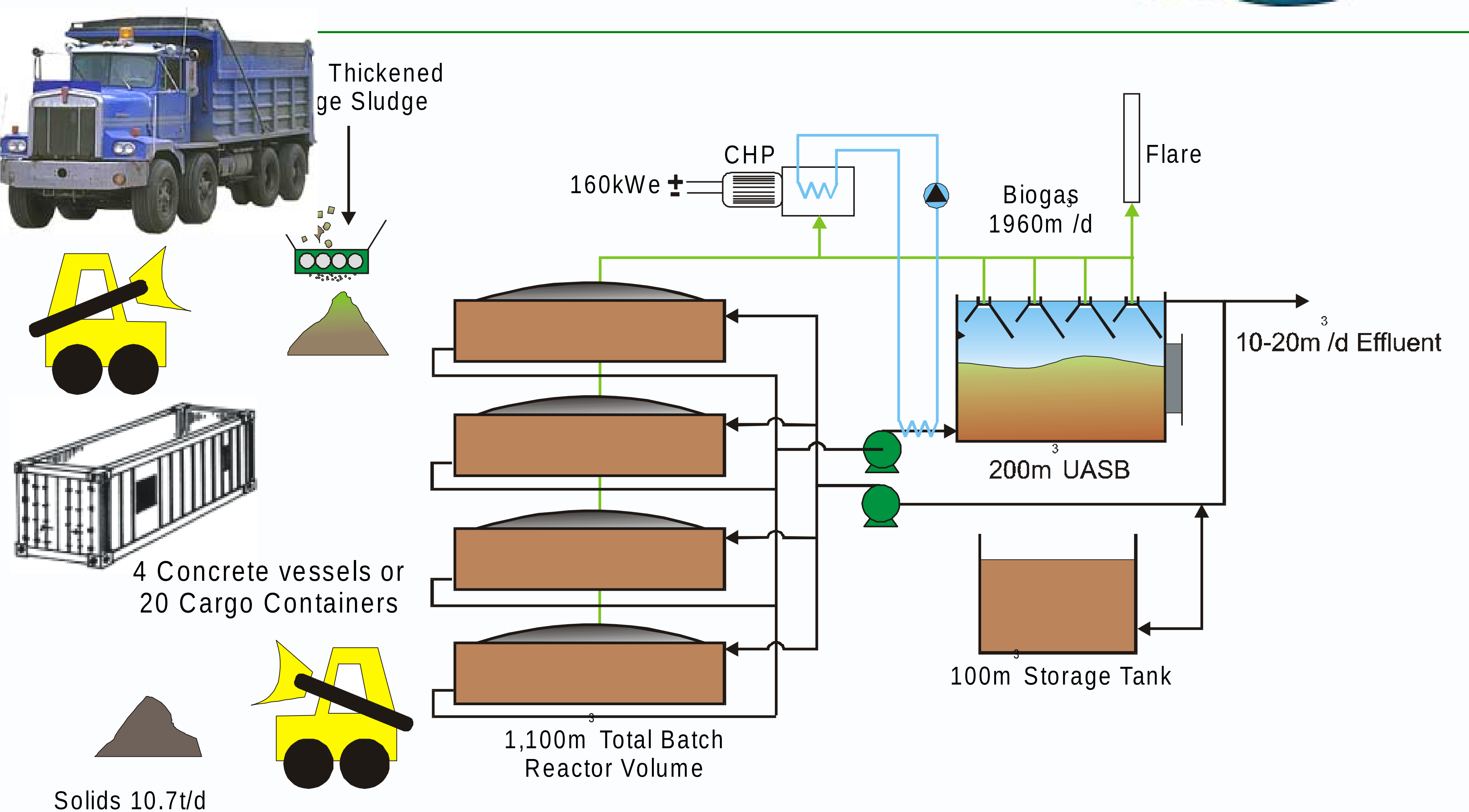
Low Solids Digester Option



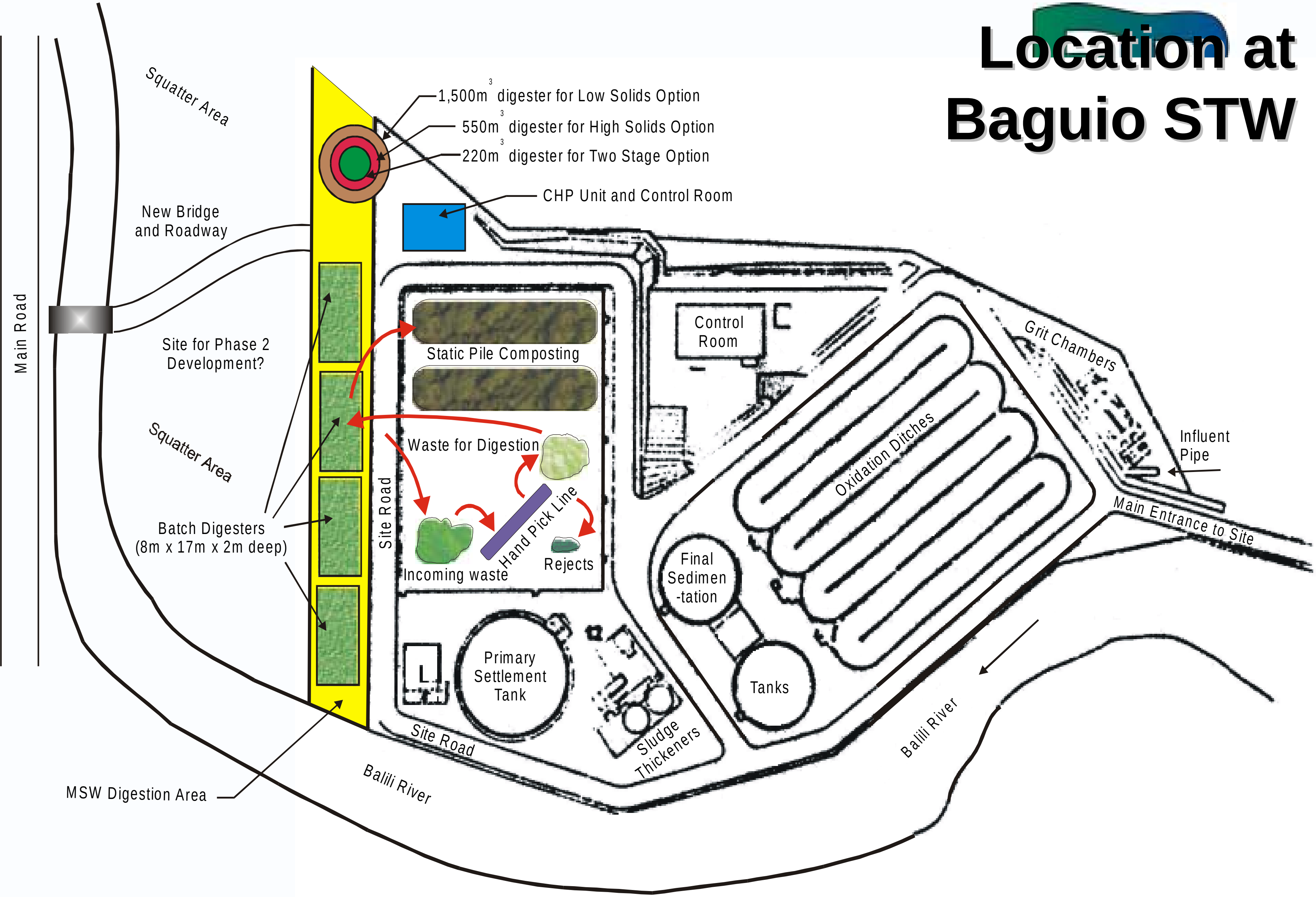
High Solids Digester Option



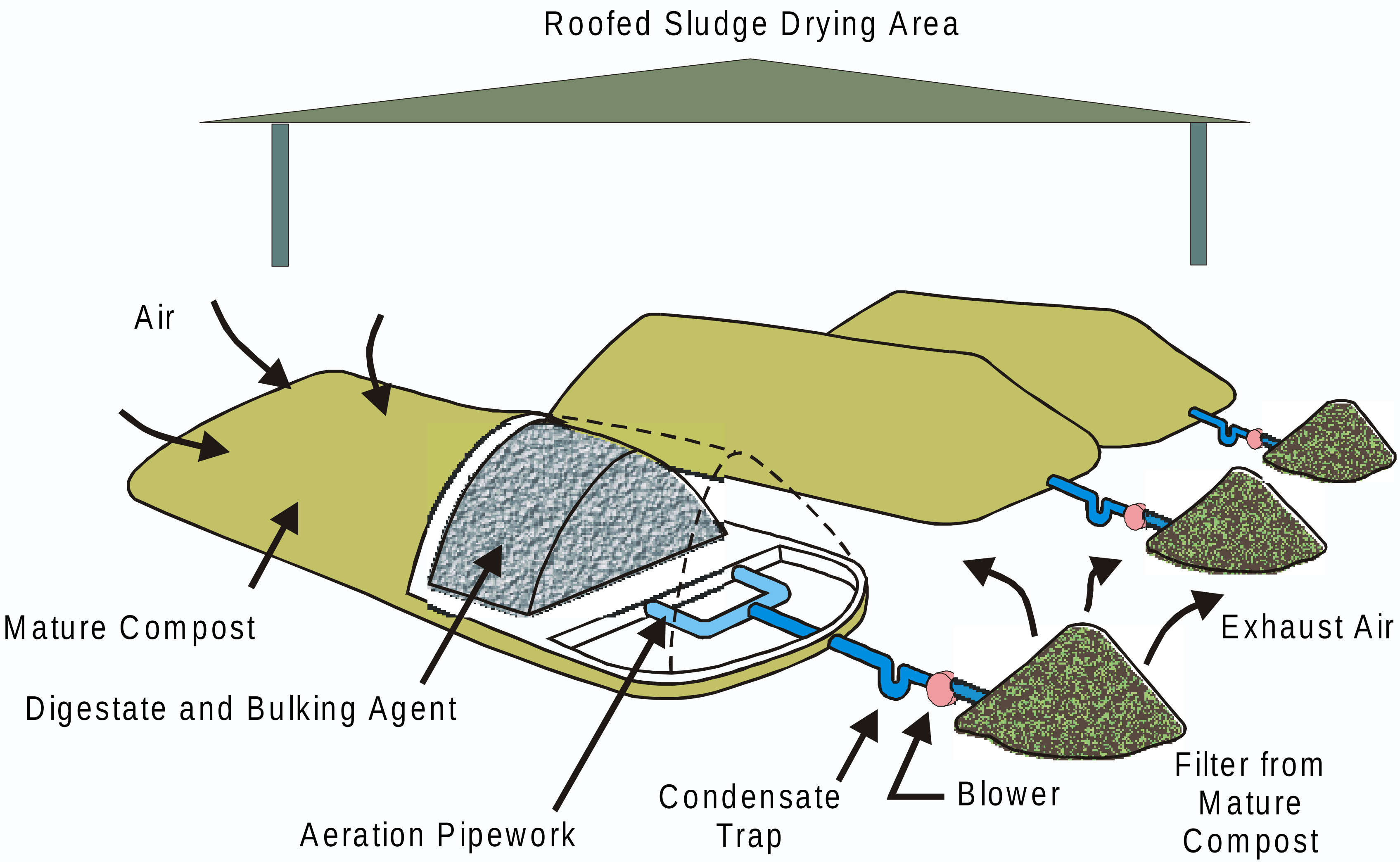
Two Stage Digester Option



Location at Baguio STW



Composting Digestate



Process Characteristics

Characteristic	***Value***
Baguio Wet Market Waste	14 t/d
La Trinidad Wet Market Waste	11 t/d
Total	25 t/d
Assumed average Bulk Density	470 kg/m3
Volume of waste per day	53.2m3
Average Total Solids	26%
Average Volatile Solids	64%
Total Volatile Solids	16.64%
Projected Biogas Potential (at 65% CH4)	1955m3/d
Electrical Energy	**160 kWe**
Solid Digestate at 60% solids recovery	3,900t/y
Compost including bulking agent	**7,800t/y**

Process Economics

	PhP (million)	£'000
Revenues		
- Tipping Fee	3.47	50
- Electricity	4.42	63
- Compost	8.18	117
	16.07	230
Operating Costs	10.72	153
Revenue	5.3	230
Total Project Costs	42.11	601

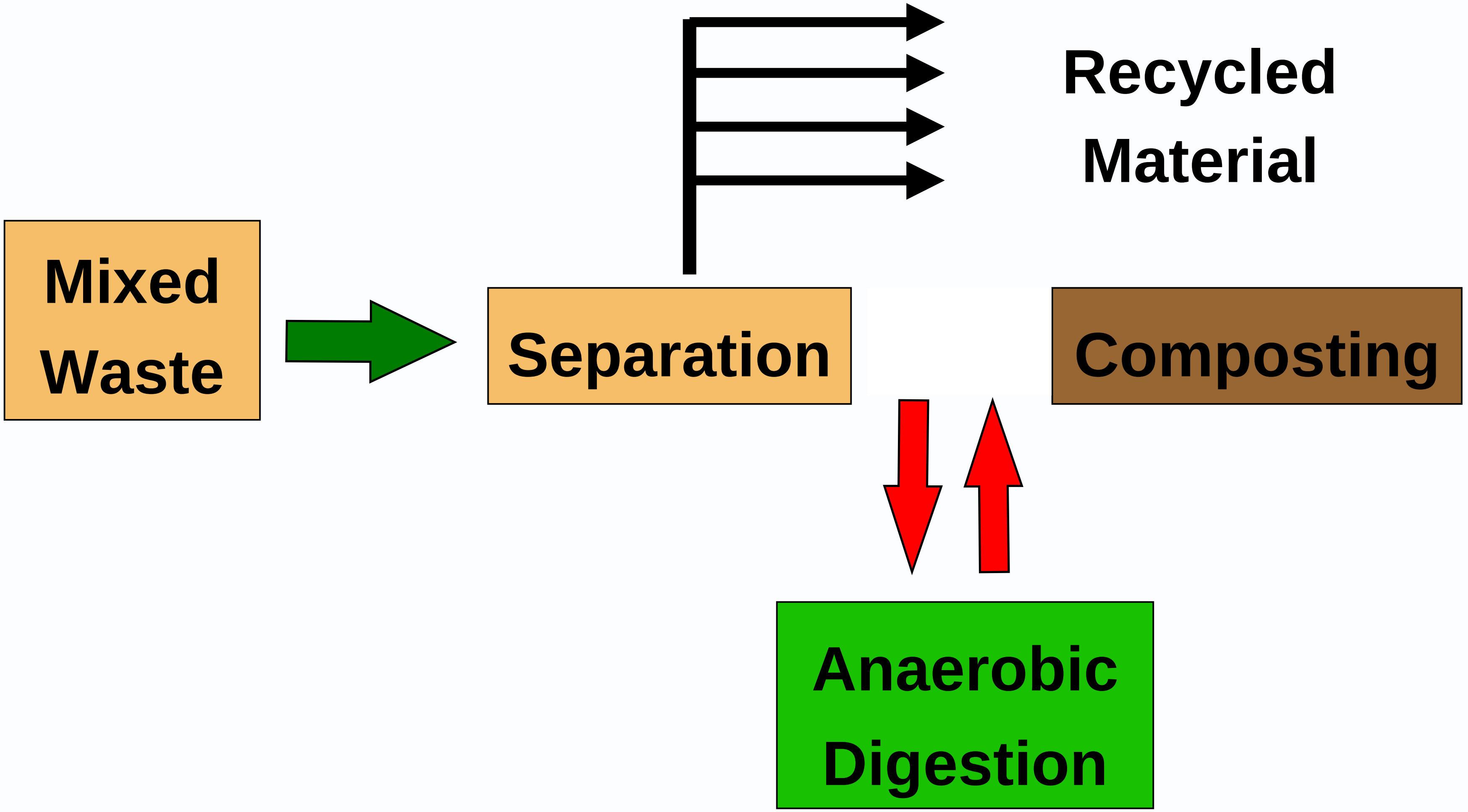
Baguio Project Development

Phase 1 : 25t/d Wet Market Waste

Phase 2 : + 70t/d 50% Baguio MSW

Phase 3 : +70t/d 50% Baguio MSW

MSW Treatment



Akras Herb & Essence Waste

Anaerobic Digestion of High Solids Wastes

Anaerobic Digestion of MSW

Overview of renewables support measures to date

- NFFO introduced in 1990 Electricity Act
- 5 Orders (& 3 in Scotland, 2 in NI)
- over 3600 MW contracted
- only 950 MW built so far
- low prices
- long period of consultation
- Start of Renewables Obligation

NFFO – non fossil fuel obligation

- Competitive tendering for banker-friendly contracts
- Bankers became familiar with renewables and NFFO contracts
- Supported range of technologies
- kick started industry & brought prices down
- but commissioning very slow

NFFO (1 - 3) and AD

- **NFFO1**
- **3 contracts awarded for AD projects (NI SG) All commissioned.**
  - **0.88 MW, Heathfield, Devon**
  - **0.17 MW, Ham Sewage Treatment Works, Somerset**
  - **3MW, Avonmouth Sewage Treatment Works, Avon**
- **NFFO2 & 3 No AD**

- **NFFO4, 6 contracts awarded for AD projects**

Status as of April 2002

- LRZ Ltd
  - **Eye Airfield** **1.05** **No PA made**
- AGTEC Ltd
  - **Spalford ADS, Lincs** **1** **No PA made**
  - **Whitchurch Hydro ADS, Shropshire** **2** **No PA made**
  - **Hydro Leeming AD, N. Yorkshire** **0.5** **PA approved**
  - **Hydro Seamer ADS, N Yorkshire** **0.6** **No PA made**
- Holsworthy Biogas Company
  - **Holdsworthy, Devon** **1.43** **Commissioned**
- **NFFO5 AD not eligible to enter**

Which RE sources are eligible?

- All non thermal RE sources (excluding hydro >20MW)
- Various restrictions on Biomass
- Where MSW is a fuel only gasification, pyrolysis or AD technology qualifies.
- With exception of certain hydro projects, nothing built before 1990, unless refurbished
- If it has a NFFO contract which was not terminated properly
- AD in - (provided OK re. bullet points 4 & 5)

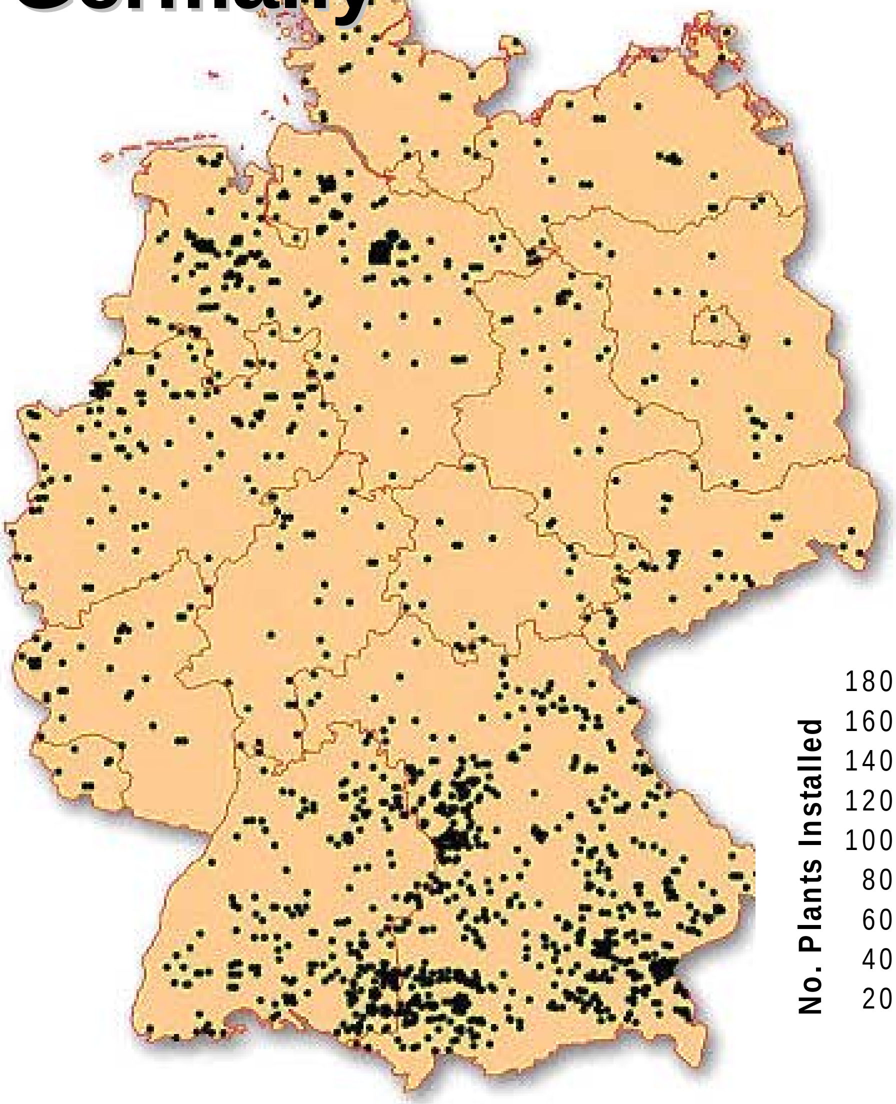
Biogas incentives in Germany

- German Renewable Energy Act (1.4.2000)
- Electricity 20 year min price
- 30% capital refund after construction (grant)
- Long term soft loan

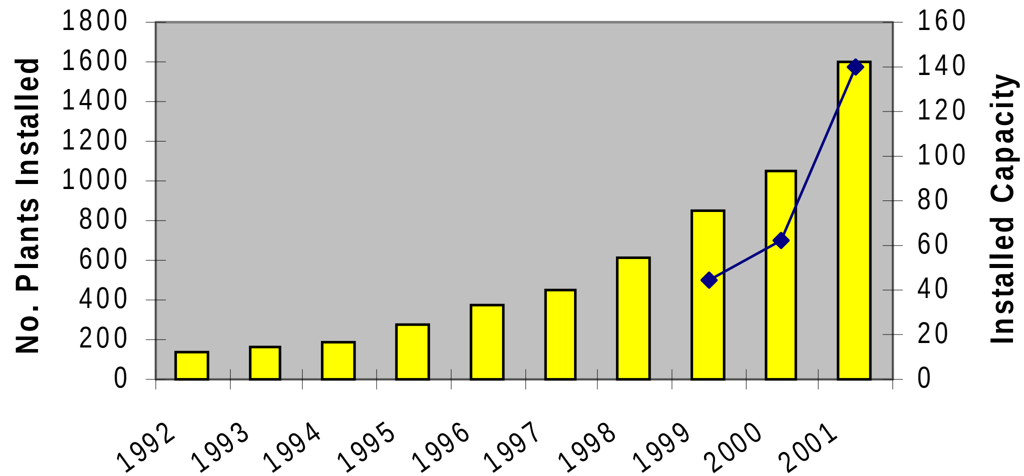
Biogas incentives in Germany

- 150 developers and installers of new systems
- 1000 new plants installed
- > 2000 new jobs
- now stopped…

Germany



Biogas Development



Biogas incentives in Germany

Compensation in Cent including 1% annual reduction

	2002	2003	2004	2005
Up to 500 kWe	10.1	10.0	9.9	9.8
Up to 5 MWe	9.1	9.0	8.9	8.8
Up to 20 MWe	8.6	8.5	8.4	8.4

Conclusions

- Technology available and developing
- Poor implemention – lack of understanding
- Needs careful incentivisation
- Barriers – public perception, scale, cost
- Developments – new forms of ownership, project development and operation

The End