LANDFILLS,
compared to
OTHER BIOMETHANATION ALTERNATIVES
for
DISPOSAL OF MUNICIPAL SOLID WASTES

Don Augenstein[1]
Ramin Yazdani[2]
John Benemann[1]

1. IEM, Palo Alto CA 94306 . . . .
2. Yolo County Department of Public Works, Woodland CA 95695

WASTE-TO-METHANE

= “BIOMETHANATION”
OR “ANAEROBIC COMPOSTING” (I E A)

Advantages (in principle) renewable energy—and waste should go away

EXAMPLE: MSW a-CELLULOSE

$(C_6H_{10}O_5)_n + nH_2O \Longrightarrow 3nCH_4 + 3nCO_2$

Early work: (a) Buswell, (b) Dynatech R/D, Cambridge MA (c) Pfeffer
Much early small-scale work: Continuous stirred tank reactor (CSTR). Modified wastewater digester feasible for close control

“INTENSIVE” PROCESSING
FOR
WASTE STREAM DIGESTION IN
STIRRED TANK (CSTR)

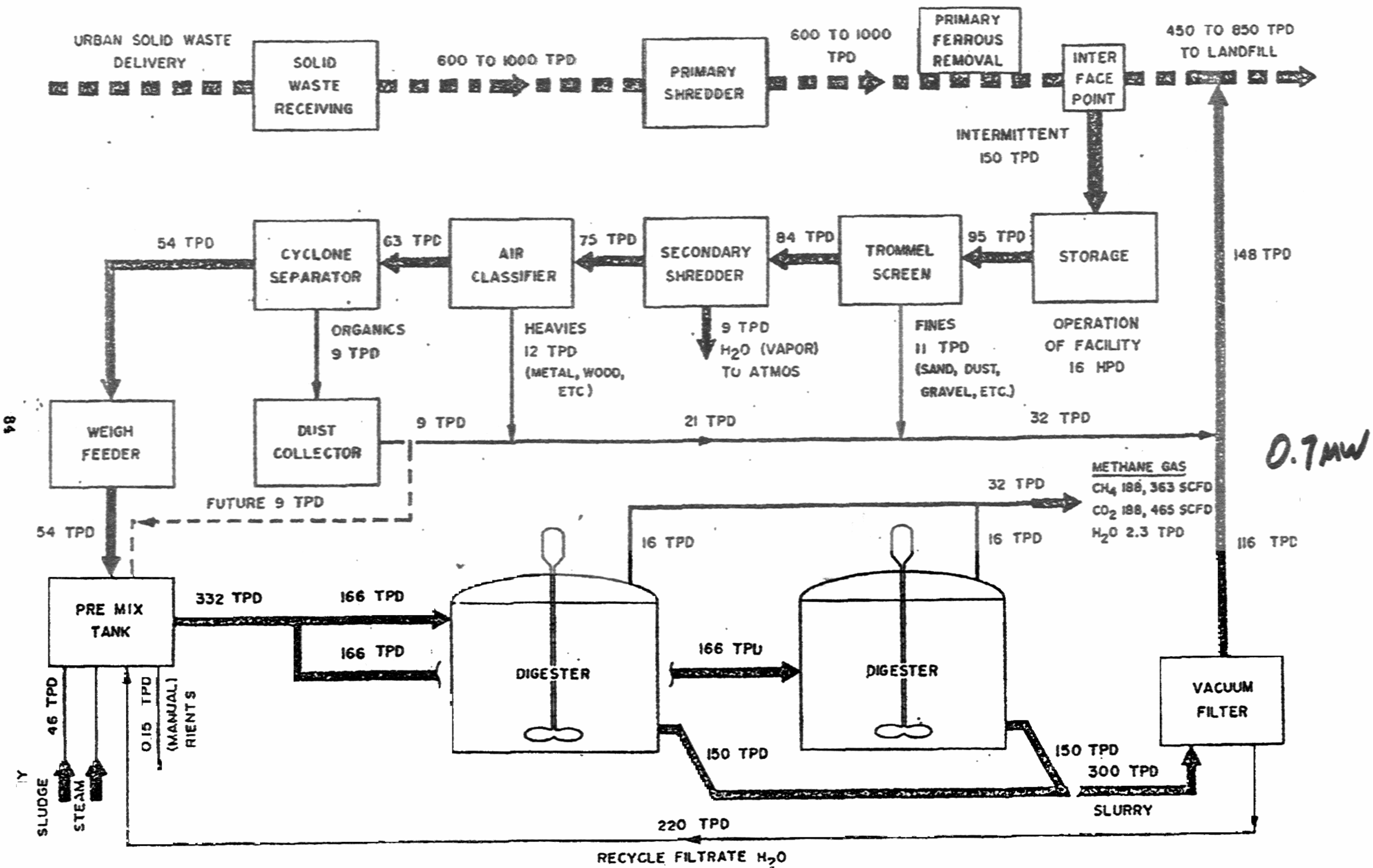
1. Receive waste, remove large inerts
2. Size reduction
3. Scrap metal removal
4. More cleanup by air classification, trommeling, etc

Digestion

Mix waste with 10x its weight water
Stir (10 to 40 days)
Filter residue; dispose of filter cake

Dispose of all gaseous, liquid and solid remnants

REFCOM - REFUSE CONVERSION TO METHANE



PROBLEMS WITH STIRRED TANK APPROACH INCLUDE

Size reduction energy, cost
Inefficient organics separation
Kinetic limitations on conversion in stirred vessels
Environmental and cost issues for process remnants

Many other problems

ENERGY INPUTS INTO SIZE REDUCTION

(From Tchobanoglous, 198?

For preliminary size reduction, add 15 hp • h/ton

Input material factors	
Municipal solid wastes	1.00
Presorted municipal solid waste	0.65
Wood and fibers only	0.45
Automobile bodies	2.82

Product size factors	
6-in product	1.00
4-in product	1.39
2-in product	1.64
1-in product	2.38

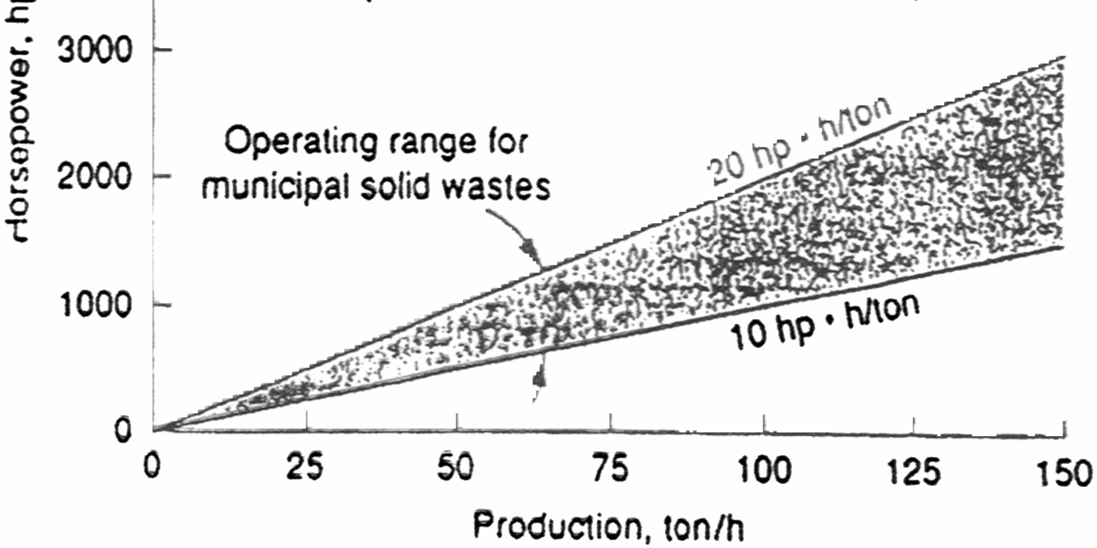


FIGURE 12-6
Horsepower requirements for hammermill shredding.

SIZE DISTRIBUTIONS FOR VARIOUS COMPONENTS OF MSW

(From Tchobanoglous, 198?)

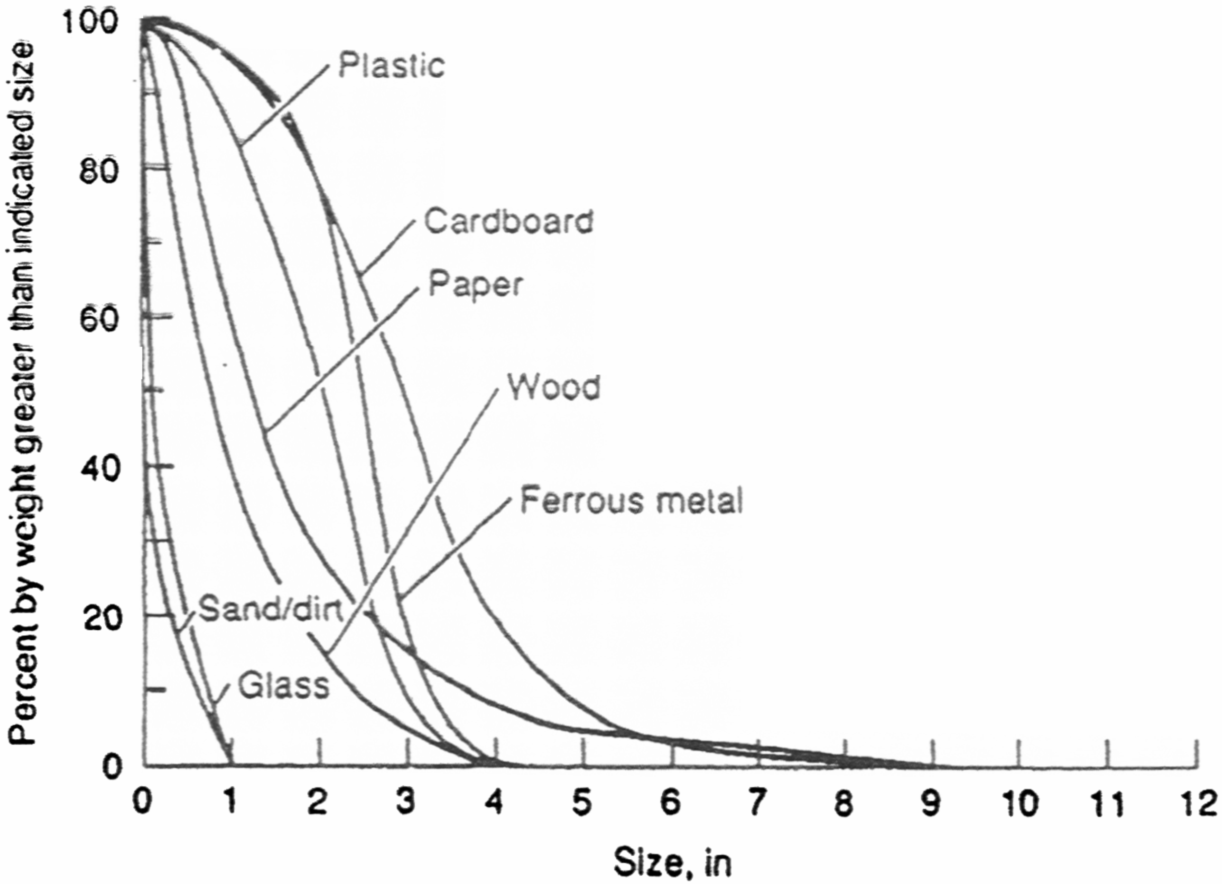
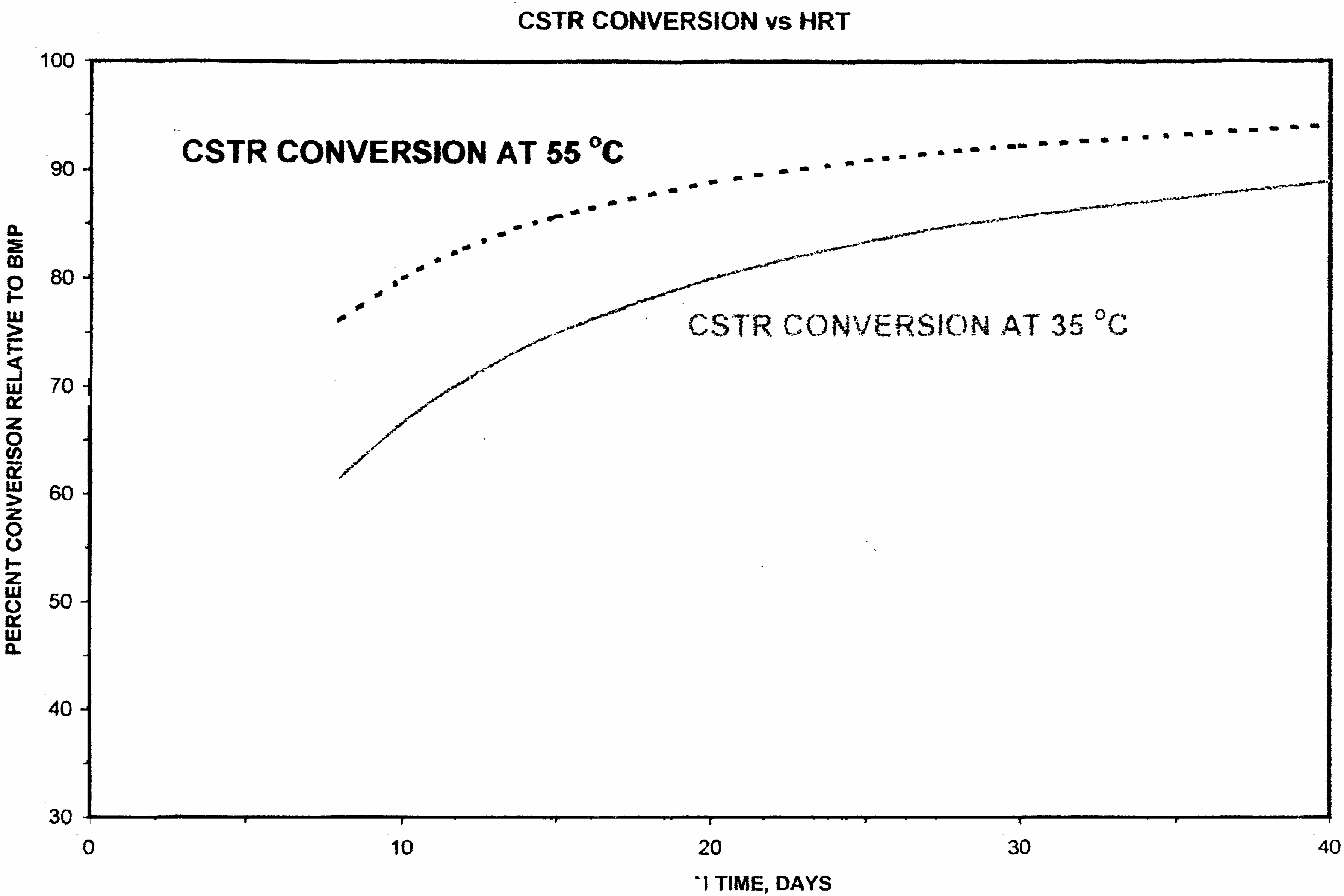


FIGURE 12-5
Representative size distribution by weight of hammermill-shredded MSW.

CONCLUSIONS: SIZE REDUCTION TOO EXPENSIVE, SEPARATION IS IMPERFECT



CSTR CONVERSION vs HRT
CSTR CONVERSION AT 55 °C
CSTR CONVERSION AT 35 °C
PERCENT CONVERISON RELATIVE TO BMP
100
90
80
70
60
50
40
30
0
10
20
30
40
'I TIME, DAYS

ENERGY EFFICIENCY AND COST-EFFECTIVENESS OF IN-VESSEL CSTR PROCESS

A. <u>PARASITIC ENERGY: IN-VESSEL PROCESS</u>

OPERATION	ENERGY AS FT^3 METHANE (=1000 BTU)/ TON MSW
SHREDDING/ SIZE REDUCTION	≈ 200-400
VESSEL MIXING (0.1-1 HP/1000FT3	≈ 100-200
HEATING (9 % SOLIDS)	≈ 200-600
FILTRATION, PUMPING	≈ 100-200
OTHER (ASSORTED)	<u>≈ 500-600</u>
TOTAL	**1000-2000**

B. <u>ECONOMICS-VERY POOR</u>, GAS, > > **10x MARKET**

DIVERSION FROM LANDFILLS

C. <u>RESIDUES (PER TON INITIAL MSW INFLOW)</u>

IN: 2000 LB MSW 1600 lb. DRY SOLIDS, + 400 LB. = 20% MOISTURE
OUT: 2000 LB RESIDUES 1300 lb SOLIDS + 700 LB MOISTURE . . . . ..

2000LB. 20% MOISTURE IN--2000LB. 35% MOISTURE OUT

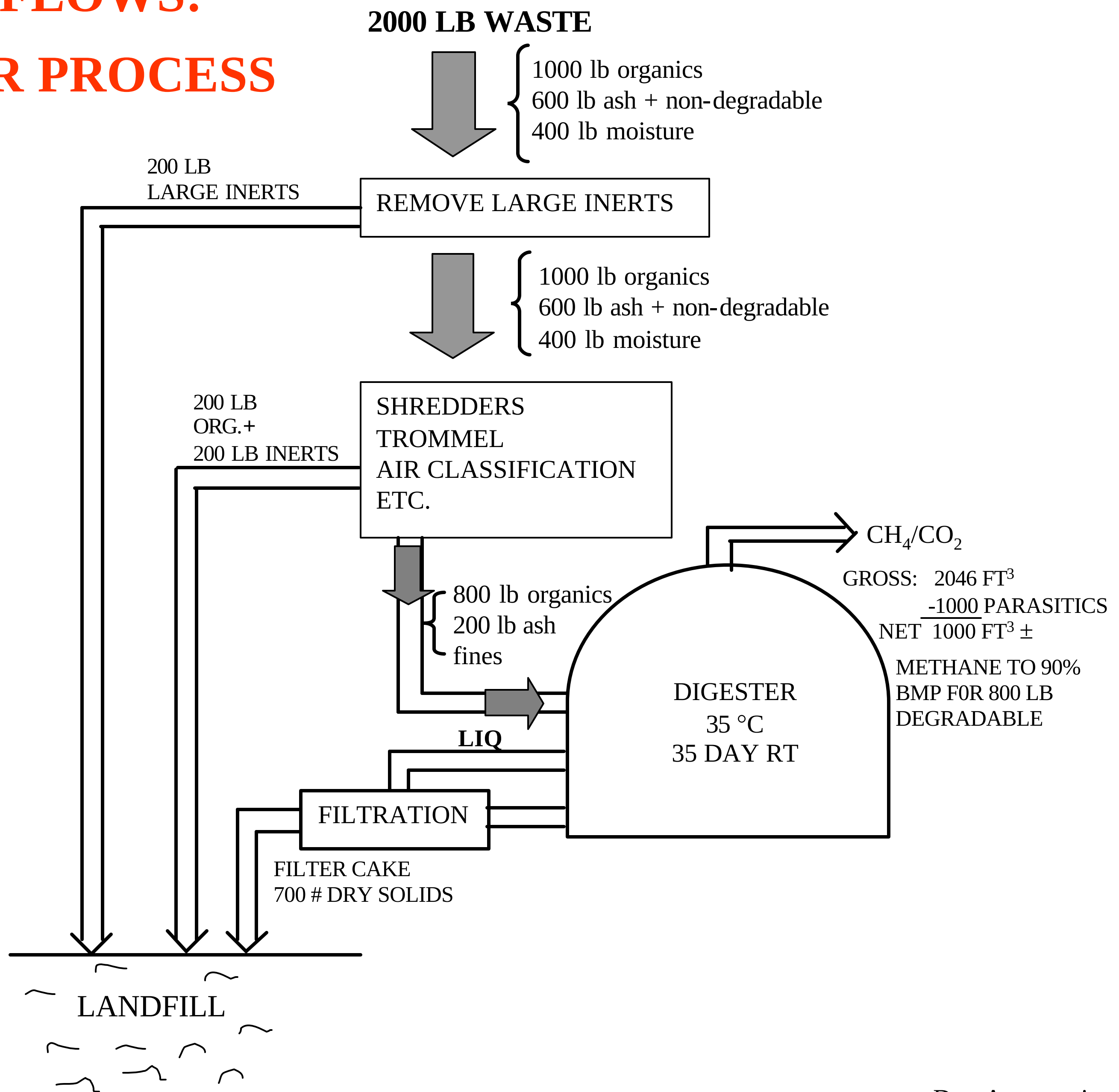
WE DO NOT DIVERT MUCH (IF ANY) MSW FROM LANDFILLING (OR PROCESSING ALTERNATIVES, SUCH AS COMPOSTING)

D. <u>REMAINING METHANE POTENTIAL FROM UNCONVERTED RESIDUES FROM IN-VESSEL WASTE-TO-METHANE PROCESS</u>

» **700 FT3/TON MSW INPUT**

—SO, STILL GET GAS IF PROCESS MSW RESIDUES LANDFILLED.

ESTIMATED FLOWS:
IN VESSEL CSTR PROCESS



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SUMMARY OF STIRRED TANK ANALYSIS

Consumes most of the energy it produces
Economics terrible
Does not substantially reduce waste disposal needs
Unconverted/sidestream organics mean
major methane problem remains

STIRRED TANK DILEMMAS (DYNATECH 1974)

HELP!! TERRIBLE ECONOMICS!! JOBS ARE AT STAKE (OURS, NO LESS!!)

SO---ALTERNATIVES?---------CAN WE OVERCOME STIRRED TANK BIOMETHANATION COST AND PROCESSING PROBLEMS?

ARE THERE REALLY NEEDS FOR INTENSIVE MSW PROCESSING, STIRRING, ETC. ETC?

Dynatech, 1974 (a) calculate stirring need (b) lab tests.

RESULTS -Don't need to stir. High solids OK

-MANAGED LANDFILL SUGGESTED

Journal Article 1976 -"Fuel Gas Recovery from Controlled Landfilling of MSW" LED TO MOUNTAIN VIEW DEMONSTRATION

LAB AND FIELD DEMONSTRATIONS

BIOREACTOR OR CONTROLLED LANDFILLS

Lab tests Dynatech 1976
—conversion rates and endpoints are great.
--Space velocity close to stirred tank work
--Yield 30-60% higher than in stirred tank

FIELD TESTS Mountain View—3-8x normal landfill rate

Other: Delaware Solid Waste Authority
Brogborough, UK
Yolo County CA

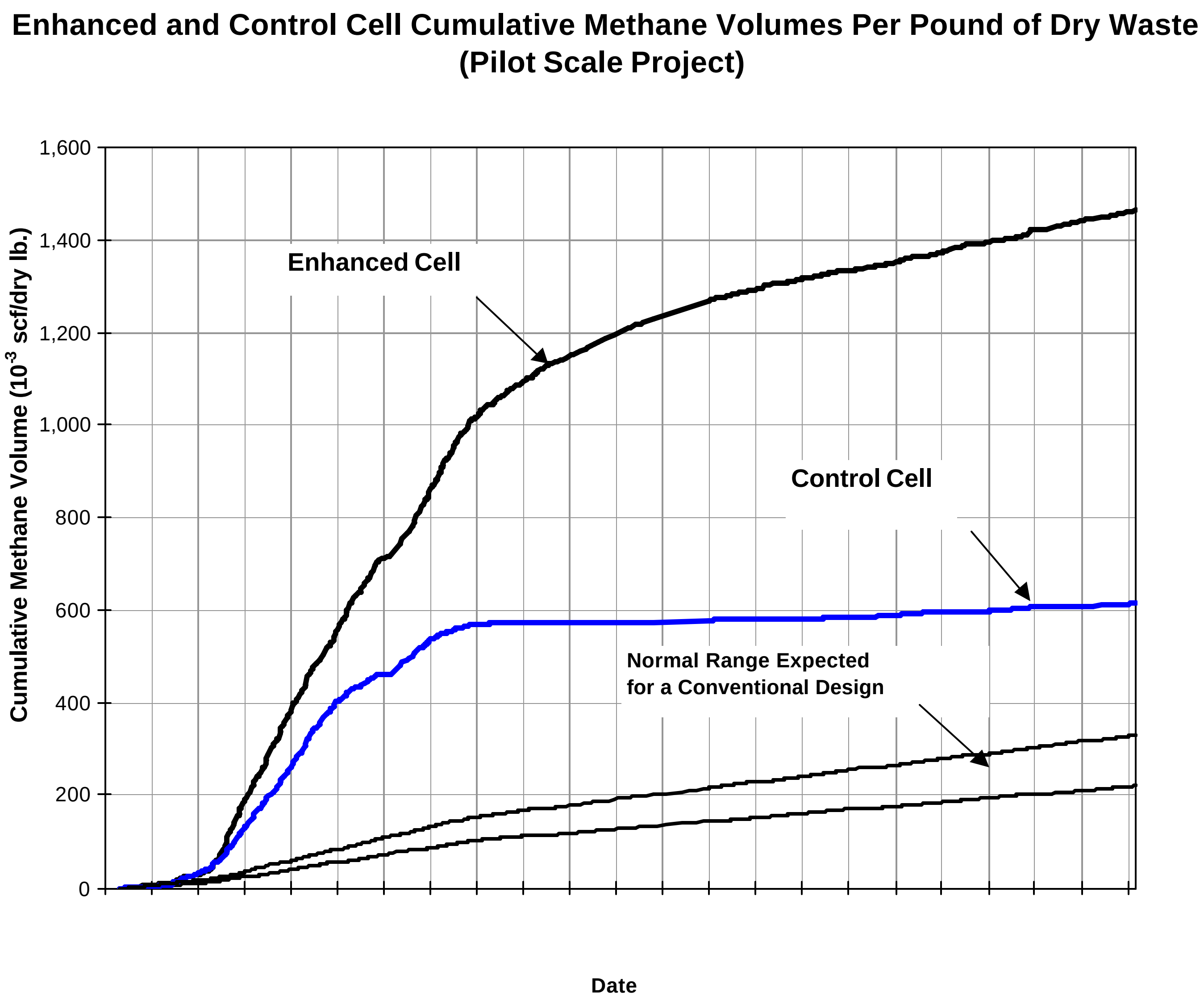
YOLO COUNTY "CONTROLLED LANDFILL" BIOREACTOR

(BIOREACTOR REFERENCE CASE FOR EVALUATIONS)

Fill waste
Cover with permeable layer and membrane for gas collection
Add moisture
Collect LFG (95+% efficiency) using slight vacuum beneath cover

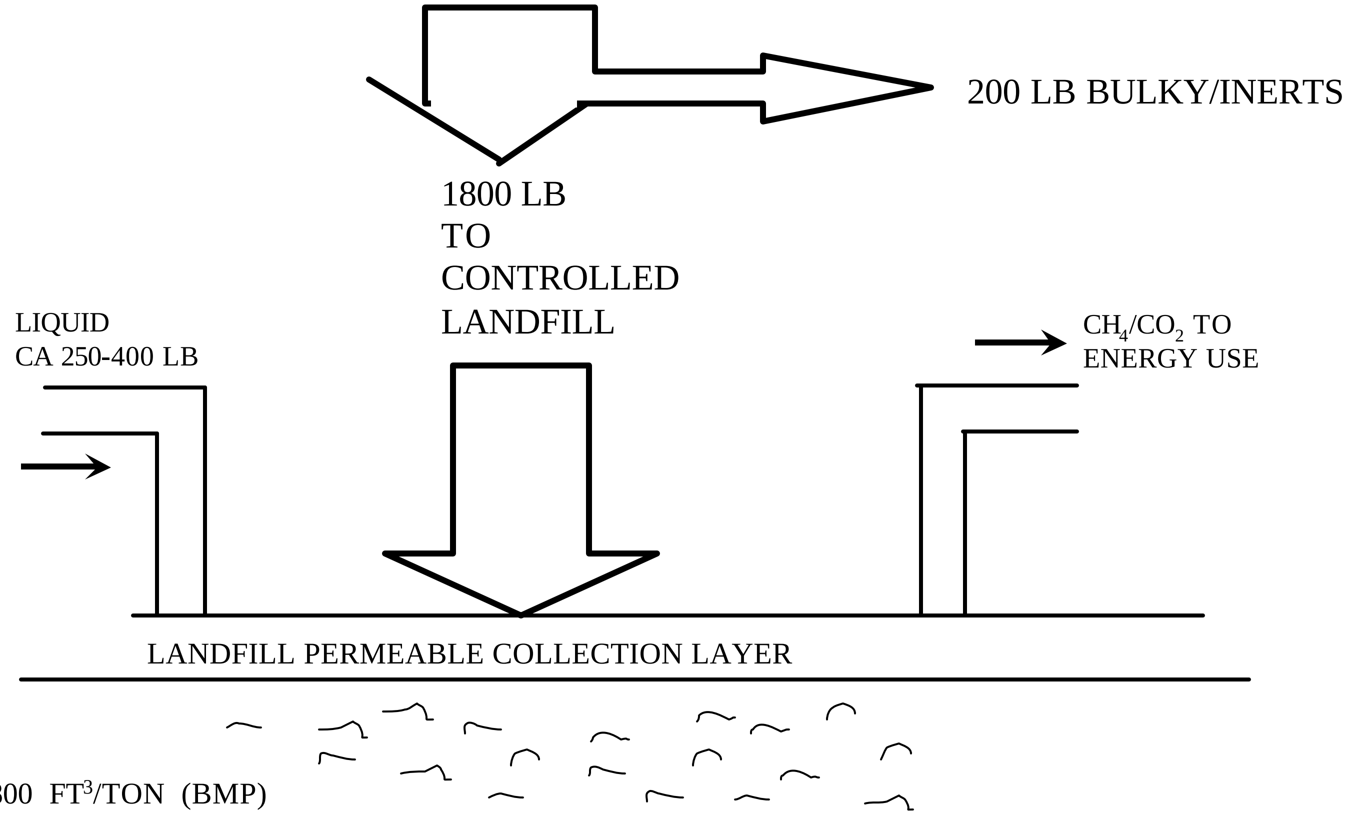
DEMONSTRATION ONGOING--RESULTS

5-10x acceleration of gas recovery
Many measured parameters highly favorable
—moisture distribution,
-volume loss,
-Temperature
-Liquid flows highly manageable


Enhanced and Control Cell Cumulative Methane Volumes Per Pound of Dry Waste
(Pilot Scale Project)
Cumulative Methane Volume (10-3 scf/dry lb.)
1,600
1,400
1,200
1,000
800
600
400
200
0
Enhanced Cell
Control Cell
Normal Range Expected
for a Conventional Design
Date

MATERIAL AND ENERGY FLOW---CONTROLLED BIOREACTOR LANDFILL

INFLOW: 2000 LB (1 US TON) POST RECYCLING RESIDUALS



TOTAL METHANE GR. 2800 FT^3/TON (BMP)
- 280 FUGITIVE, UNRECOVERED
- 120 PARASITICS

NET ENERGY 2400 FT^3 (2.4×10^6 BTU)

TOTAL COST ≈ \$ 0.50 – 8,00 / 1 MILLION BTU
(REPORT DE-AC26-98FT 40422)

Don Augenstein

ENVIRONMENTAL IMPACTS:
CONTROLLED LANDFILL Vs. IN-VESSEL FOLLOWED BY RESIDUE COMPOSTING (Basis 1 ton total MSW in)

CONTROLLED LANDFILL A WINNER ON

Net Energy
Landfill Life Extension
VOC Abatement
Greenhouse Gas Emissions

BETTER IN-VESSEL PROCESSES

HIGHER SOLIDS

THERMOPHILIC OPERATION

MINIMAL OR NO MIXING

SOURCE SELECTION OF WASTES,
CONCENTRATE ON FOOD

<u>MAJOR EFFORTS IN EUROPE</u>

EUROPEAN IN-VESSEL DIGESTION COMPANIES INCLUDE -DRANCO, KOMPOGAS, VALORGA

I. EXAMPLE: KOMPOGAS SITES

1. Rümlaung, Switzerland start 1989, 500T/y
2. Rümlang, Switzerland, start 1992, 3500 t/y for: Electricity, cars, heat
3. Bachenbülach Switzerland, start 1994 10,000 ton/y Electricity, cars
4. Samstagern, Germany, 10000T/y start 1995 Intended for pipeline gas
5. Kempten, Germany 10,000 t/y start 1996 Electricity
6. Otelfingen, Switzerland, 1996, 12,000 t/y Electricity, cars
7. Braunschweig, Germany 1997 Electricity
8. München-Erding Germany 1997 24,000 t/y Electricity
9. Standort: Lustenau Austria 1997 10,000 t/y Existing electricity plant
10. Hunsrück Germany 1997 10000 t/y Electricity
11. Niederuzwil Switzerland 1998 8000 t/y Electricity

12 Kyoto Japan 1999 1000 t/y Electricity

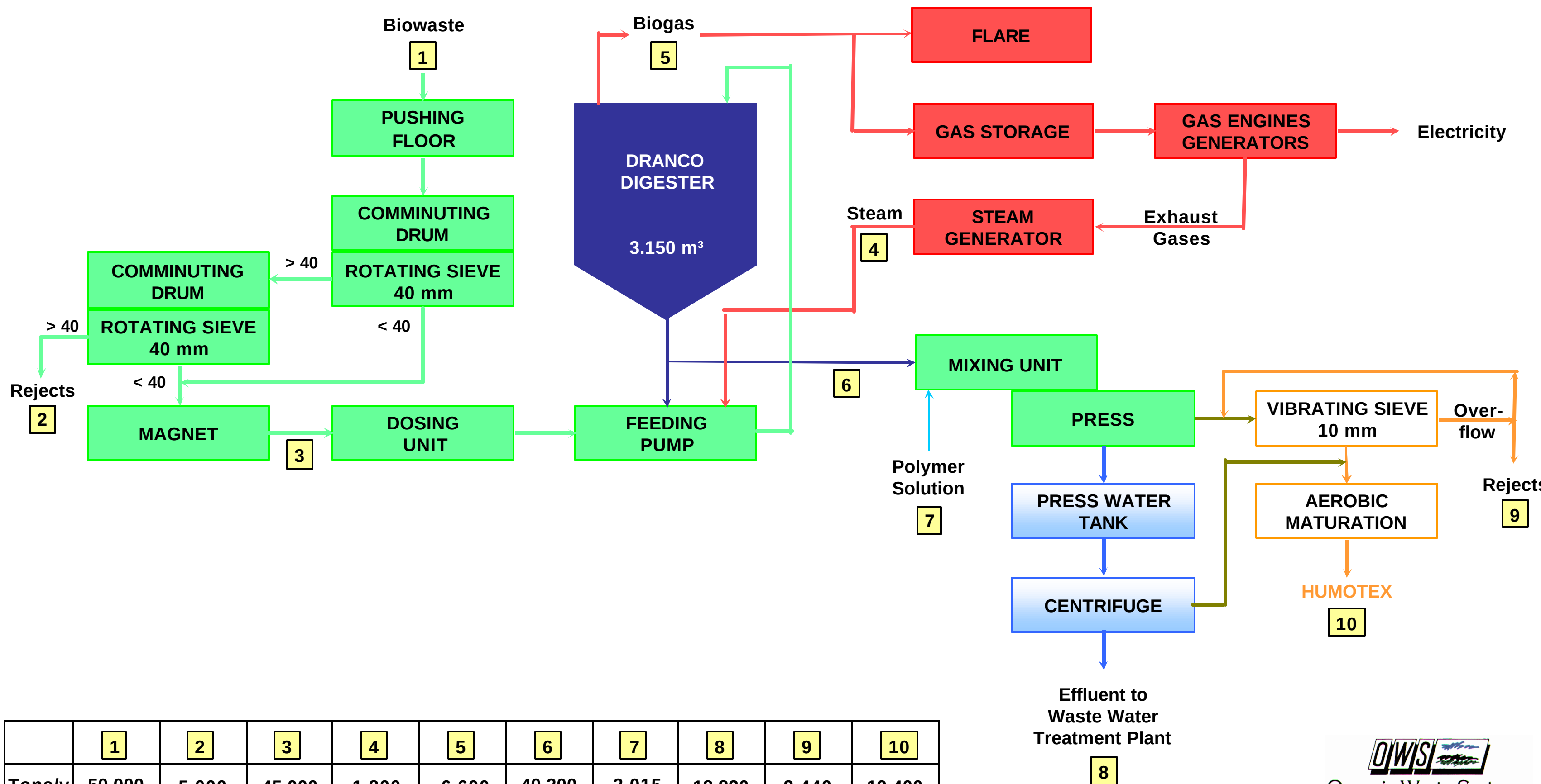
13 Alzey-Worms Germany 1999 24,000 t/y Electricity

14 Frankfurt Germany 1999 15,000 t/y Electricity

II **OVER 50 EUROPEAN FACILITIES - - -- - - <u>BUT</u>**

III Processing under 2% of European Waste

DRANCO PLANT BRECHT II (BELGIUM)



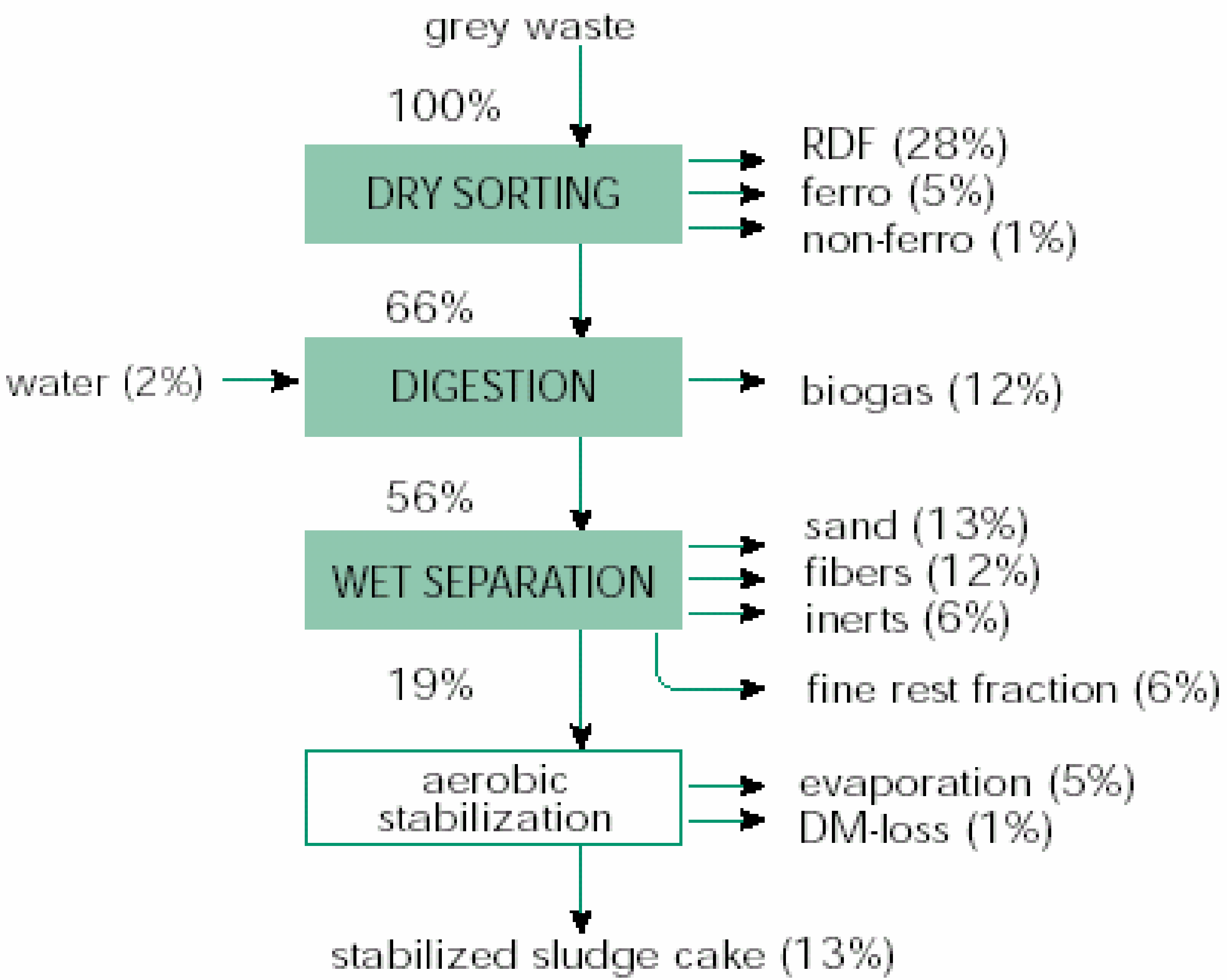
	1	2	3	4	5	6	7	8	9	10
Tons/y	50.000	5.000	45.000	1.800	6.600	40.200	3.015	18.830	2.440	19.400

Organic Waste Systems

CCI Newmarket Plant

- Design capacity of 150,000 metric tonnes of organic waste per year
- Accepted its first load of waste July 14, 2000.
- 2.209 hectare (5.4acre) site
- 60,000 tonnes of compost
- 5,000 kW of electricity
- Produce enough surplus power for 3,000 homes


BIOGAS


grey waste
100%
DRY SORTING
RDF (28%)
ferro (5%)
non-ferro (1%)
66%
water (2%)
DIGESTION
biogas (12%)
56%
WET SEPARATION
sand (13%)
fibers (12%)
inerts (6%)
fine rest fraction (6%)
19%
aerobic stabilization
evaporation (5%)
DM-loss (1%)
stabilized sludge cake (13%)

ENERGY BALANCES/COSTS FOR ANAEROBIC "MSW" DIGESTION
(European high-solids vessel approaches)

FROM: A Wellinger, Economic Viability of Anaerobic Digestion (1995)

PROCESS	Units	Kompogas	Dranco	Valorga
Temperature	thermo/meso	thermo	thermo	meso
Capacity	tonnes/year	10,000	10,000	52,000
Power use	kWh/tonne MSW	35	33	75
Power out	kWh/tonne MSW	75	79	78
Capital costs	US million	$6	$7	$35
Operating costs	US M/Y	$0.6	$0.6	$1.7
Total cost	$US/tonne MSW	$105	$121	$104

EUROPEAN EXPERIENCE WITH HIGH-SOLIDS
IN-VESSEL DIGESTERS

Many plants **but**
Only processing small fraction (ca. 1%) of European Waste

PROBLEMS AS WITH CSTR

Almost no net energy
Methane emissions likely

ENVIRONMENTAL ISSUES
--BIOREACTOR GROUNDWATER RISKS-

COMPARISON AGAINST LIKELY ALTERNATIVES

1. **COMPOSTING OVER SOIL OR PAD?**
   Draining liquid poses risk

2. **IN-VESSEL BIOMETHANATION FOLLOWED BY COMPOSTING OR LANDFILLING?**
   Risks as with landfilling or composting

3. **BIOREACTOR LANDFILL**
   Risk less than alternatives.

From IEM, 1999 “Landfill Management for Carbon Sequestration and Maximum Methane Emission Control”
US Department of Energy DE-AC26-98FT40422

BASE LINER INTEGRITY AND LIFETIME

LLDPE LINER LIFETIME UNDER LANDFILL CIRCUMSTANCES—CENTURIES--EONS?

COMPARED WITH ALTERNATIVES

BIOREACTOR LANDFILL WITH BASE LINING, CAREFUL LIQUID AND OTHER MANAGEMENT ARGUABLY SAFEST FROM PERSPECTIVE OF GROUNDWATER RISK

FUGITIVE METHANE AND VOC's

<u>BIOREACTOR</u> AVOIDABLE WITH PROPER SETUP AND GAS EXTRACTION—95+% CAPTURE POSSIBLE (Described in NETL Report on DE-AC26-98FT40422, IEM, 1999)

(BASIC GAS FLOW PRINCIPLES ARE EXTREMELY WELL VALIDATED IN CASES OF CLEAN ROOMS FOR SEMICONDUCTOR MANUFACTURE, SURGICAL OPERATING ROOMS, ETC.)

<u>IN-VESSEL BIOMETHANATION</u>: :
VOC AND METHANE WILL STILL POSE METHANE AND VOC CONTROL REQUIREMENT (TO MUCH GREATER EXTENT THAN EXAMPLE BIOREACTOR)

SIDE SLOPE STABILITY

LESSENED SIDE SLOPE STABILITY SUSPECTED BUT LOWER SHEAR STRENGTH NOT SHOWN (Kazavanjian et al)

CAN INVESTIGATE: HISTORICAL RECORD AVAILABLE:

RAIN-SATURATED, DEGRADED OLDER LANDFILLS CAN INDICATE RISK.

MERCURY AND DIMETHYL MERCURY

TOTAL US MERCURY EMISSIONS OVER 250,000KG PER YEAR (USEPA, 1998, WEBSITE)

US LANDFILL MERCURY EMISSIONS UNDER 3 KG/Y

LANDFILL DIMETHYL MERCURY TOTAL

THOUSANDFOLD LESS THAN
DIMETHYL MERCURY FROM SWAMPS, SEDIMENTS

GREENHOUSE GAS EMISSIONS ISSUES

BIOREACTOR LANDFILL CAN PROVIDE VERY EFFECTIVE GREENHOUSE GAS REDUCTION VS. ALTERNATIVES

CAPTURE ALL GAS; CONSIDER FOSSIL CO2 OFFSETS
NET GHG IMPACT NEAR ZERO (NETL STUDY)

WHEREAS

IN-VESSEL PROCESSES HAVE MINIMAL FOSSIL CO2 OFFSET AND REQUIRE CONTROL (SOMEHOW) OF SUBSTANTIAL METHANE EMISSIONS FROM PROCESS RESIDUES

ALSO: COMPOST PILES EMIT VERY SIGNIFICANT AMOUNTS OF METHANE AND VOC'S (Edelmann, 2002, others)

SOME CONCLUSIONS

NET ENERGY OF IN-VESSEL MSW-TO-METHANE PROCESSES IS VERY SUBSTANTILLY LIMITED BOTH BY PROCESS ENERGY USE AND INEFFICIENCIES

THE IN-VESSEL PROCESSES (EUROPEAN OR OTHER) DON’T REALLY DIVERT ANY SUBSTANTIAL AMOUNT OF WASTE FROM LANDFILLS (or needs for composting)

COST OF IN-VESSEL BIOMETHANATION HAS PROVEN REPEATEDLY, REPRODUCIBLY OVER MANY YEARS TO BE DISAPPOINTINGLY HIGH

CONCLUSIONS—CONT

CONSIDERING DOCUMENTED PERFORMANCE OF ALTERNATIVES, SHOULD LANDFILLS MERIT LOWEST RANKING IN DISPOSAL?

Landfills have relative merit over composting and can achieve same ends

LANDFILLS, PARTICULARLY BIOREACTOR LANDFILLS (BIOREACTORS) CONTINUE TO PERFORM WELL RELATIVE TO OTHER MSW-TO-ENERGY BIOTECHNOLOGIES. THIS IS ON YARDSTICKS OF CONVERSION EFFICIENCY, NET ENERGY AND COST ALONG WITH CLIMATE BENEFIT. BENEFITS CAN BE OVER AND ABOVE OTHER WASTE TO-ENERGY BIOTECHNOLOGIES

(RISKS OF PROPERLY MANAGED BIOREACTORS ARE SMALL TO MODERATE AND CAN BE MITIGATED)

RESEARCH NEEDS

RENEWABLE ENERGY, ENVIRONMENTAL BENEFITS AND POTENTIAL OF BIOREACTORS SHOULD CONTINUE TO BE CAREFULLY EVALUATED AS NEWER WASTE MANAGEMENT HEIRARCHES ARE FORMULATED

:

NEED ONGOING “REAL” MEASUREMENTS TO CONTINUE COMPARISONS OF CONTROLLED LANDFILLS WITH BIOMETHANATION ALTERNATIVES

ISSUES WITH STIRRED-TANK

--PROCESSING IS ENERGY INTENSIVE
--INEFFICIENT ORGANICS SEPARATION
--CONVERSION Kinetics are barriers

LOOK AT PERFORMANCE MEASURES

Net methane energy
Cost/unit methane
How much waste reduction
Methane emission problems remaining

SOME CONTROLLED LANDFILL PARAMETERS

Net Energy
Carbon Sequestration
Landfill Life Extension
VOC Abatement
Greenhouse gas abatement

Sources: (IEM, 1999) "Landfill Management for Carbon Sequestration and Maximum Methane Emission Control. Final Report on Contract DE-AC26-98FT40422
US Department of Energy, National Energy Technology Laboratory.