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ABSTRACT

This study unit advocates the use of biomass conversion techniques with municipal solid wastes as a viable action for energy development. The unit includes: (1) an introductory section (providing a unit overview and supportive statements for biomass conversion; (2) a historical review of energy use from wastes; (3) a section on design and operation of energy recovery systems (including diagrammatic illustrations); and (4) a discussion of economic aspects of biomass recovery systems (with itemizations of cost factors and benefit areas). A list of student activities is given and a 5-day plan is outlined with a suggested program format for each day. A bibliography and list of audio-visual materials are also included. (ML)

ENERGY WORKSHOP

Dr. Arie Halachmi, Director

THE RECOVERY OF ENERGY FROM WASTE

by

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U.S. Dept. of ENERGY

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THE RECOVERY OF ENERGY FROM WASTE

Overview

Energy Specialists who plan for our future should consider using Biomass Conversion of Municipal Solid Waste as a realistic option for energy development. The skills and technology are already present at a sufficient level to make this a potential aid in combating the ever-growing need for new sources of energy. With continuing research into salvage reclamation and conversion of Municipal Solid Waste, it may be possible that even greater amounts of energy will be recovered from this resource in future years.

OBJECTIVES

Students should be able to:

1. Develop a working understanding of the overall energy picture past, present, and future.
2. Read, interpret and draw conclusions from prepared sources.
3. Have a general understanding of the carying types of Municipal Solid Waste design and operations.
4. List the benefits to be derived from the MSW facility.
5. Compare the cost of evergy and benefits from MSW plants with that of an equal amount of energy derived from other energy sources.

THE RECOVERY OF ENERGY FROM WASTE

I. Introduction

The 1973 and 1974 Arab Oil Embargo brought about an abrupt change in the ability of the industrialized nations including the United States to continue to travel a stable economic path, with a cheap plentiful supply of energy. The oil embargo in the United States led to nationwide shortages of petroleum, a $60 billion dollar drop in the Gross National Product, uncontrollable inflation, and large balance of payments deficits that continues to be one of the major concerns of the citizenry of our country. This one episode on the international stage created a worldwide energy awareness. It is as one young adult stated shortly thereafter, "Energy was a word I had not given much thought, but as the shortages began to affect my lifestyle it seemed to haunt my every move." The crucial energy policies of the present and future will have far reaching consequences to all people. Amory Lovins, a U.S. physicist and environmental activist, has suggested in his book Soft Energy Paths: Toward a Durable Peace that the alternative energy strategies facing the United States can be called "hard" and "soft" energy paths. The "hard" energy path stresses sustained growth of energy production to meet anticipated future demand as projected from past energy consumption. This strategy means a rapid expansion in coal usage, a new search for increasingly elusive oil and natural gas reserves, and continued growth of the nuclear power industry. Project Independence and the massive new synfuels program are examples of the hard energy path. This path also leads toward the continued growth well into the next century of centralized systems that generate electricity. Where the "soft" energy path emphasizes more restrained production of energy based on conservation, deliberate effort to moderate future national demand, the soft energy strategy relies on solar and other renewable energies, with more decentralization of the systems.

It is under the group heading of renewable energies that our classroom unit of study will examine the energy area of Biomass and more specifically the recovery of energy from Municipal Solid Waste (MSW) which often is referred to as "garbage."

Historically, the most ancient energy sources were utilized by the combustion of plant and animal materials. The term biomass refers to any material derived from living organisms. Plants capture and store solar energy directly through a process called photosynthesis. Animals and humans then draw on this energy source by consuming the plants. Among the materials currently available in the United States for biomass utilization are wood, agricultural and forest wastes, municipal garbage, many grains such as corn, and animal manure. Since the turn of the century fossil fuels have increased greatly displacing the traditional sources of energy, and biomass gradually shrank to insignificance in U.S. energy production as stated by Walter A. Rosenbaum in his book Energy, Politics and Public Policy. He also says the potential energy available in U.S. timberlands could yield 3 million barrels of oil per day in energy equivalent, municipal solid and liquid wastes could add an additional 1.5 million barrels to this figure providing a partial solution for two problems. The problems are: (a) What to do with our dwindling landfill sites in populated areas with an ever increasing supply of garbage, and (b) What to do about a needed supply of energy in populated urban areas.

Walter A. Rosenbaum states "In short, the Golden Age of Fossil Fuels--the decades of cheap abundant, environmentally acceptable energy production suitable to all U.S. demands--is dead."

II. History of Energy From Waste

Many Forms and By-Products

Since the beginning of Earth, man has used one form of energy in fire. He discovered fire and learned to use it, but it wasn't until man learned how to create fire that he began the journey out of the Stone Age. Providing and using energy more efficiently has been one of mankind's greatest endeavors. But only in the past century has man's use of energy threatened to overwhelm his environment. The demands for energy tapped man's creativity. One of the earlier forms of energy was man power used by the Egyptians to build pyramids. The energy technology grew as man learned to harness the wind, windmills, and sailing ships, and the production of the wheel. The wheel helped to bring about the Industrial Revolution. The Industrial Revolution brought machines for converting energy from one form to another that irrevocably changed man's life and his relationship to his environment. First, the steam engine made energy portable on a large scale. Second, the internal combustion engine. Petroleum products, before the internal combustion engine, had been used mainly for patent medicines, although Kerosene had replaced whale oil and candles and was beginning to be used for heating. Steam and petroleum brought about large scale changes in man's environment. The steam engine less than a hundred years ago was joined to a generator and the first central power generating station turned on the lights in a single block of New York City. The petroleum by products or waste was used for the combustion engines. Man's discovery of the fire or the energy from fire has brought about waste. It is from waste that man has found useful by-products. Two are Biomass and energy frc~ waste (MSW) in the form of steam or gasses to produce electric'.

Biomass is the oldest source of energy known. Man first used biomass in the form of wood, other biomass products are crops, animal manure, kelp and Algae. During World War II many nations worked to develop the fuel potential of trees; Sweden, for example, cultivated large forest areas specifically for energy consumption and research.

Waste products from crops of sugar beets, sugar cane, sweet sorgham, and grains help to make ethanol (ethyl Alcohol).

Animal manure is a source of methane gas which can be manufactured by a process called anaerobic digestion.

The waste or end by products of kelp and algae produce biomass sources. Through a process called biophotolysis, bluegreen algae produces hydrogen as a waste product. Kelp produces hydrogen gas through photoelectrolysis, a photochemical process which uses a catalyst to separate hydrogen and oxygen.

Energy from waste is another form of energy that was used during World War II by the Europeans to turn MSW, (Municipal Solid Waste) often referred to as "garbage," into steam, which can be used directly or converted to electric power, hot water, or chilled water. The MSW in Western Europe was burned in large waterwall furnaces.

The MSW in the United States is producing at the rate of 135 million tons annually. MSW contains over two-thirds of the national consumption of paper and glass, over one-fifth of the aluminum, and nearly one-eighth of the iron and steel. Some of the items from MSW could be recovered under MRS (Materials Recovery System), such as ferrous metal, aluminum, or glass. The recovery system is not always fessible. Other materials that can be recovered are paper fiber, compost, and other nonferrous metals.

Several Acts have established national policies and programs for technologies which reclaim materials and energy from MSW.

III. Design and (eration of Energy Recove. / Systems

Waterwall Incineration

In the waterfall incineration of raw Municipal Solid Waste (MSW) is burned directly in large waterfall furnaces, generally without pre-prossing the waste. The primary product is steam, which can be used directly or converted to electric power, hot water, or chilled water.

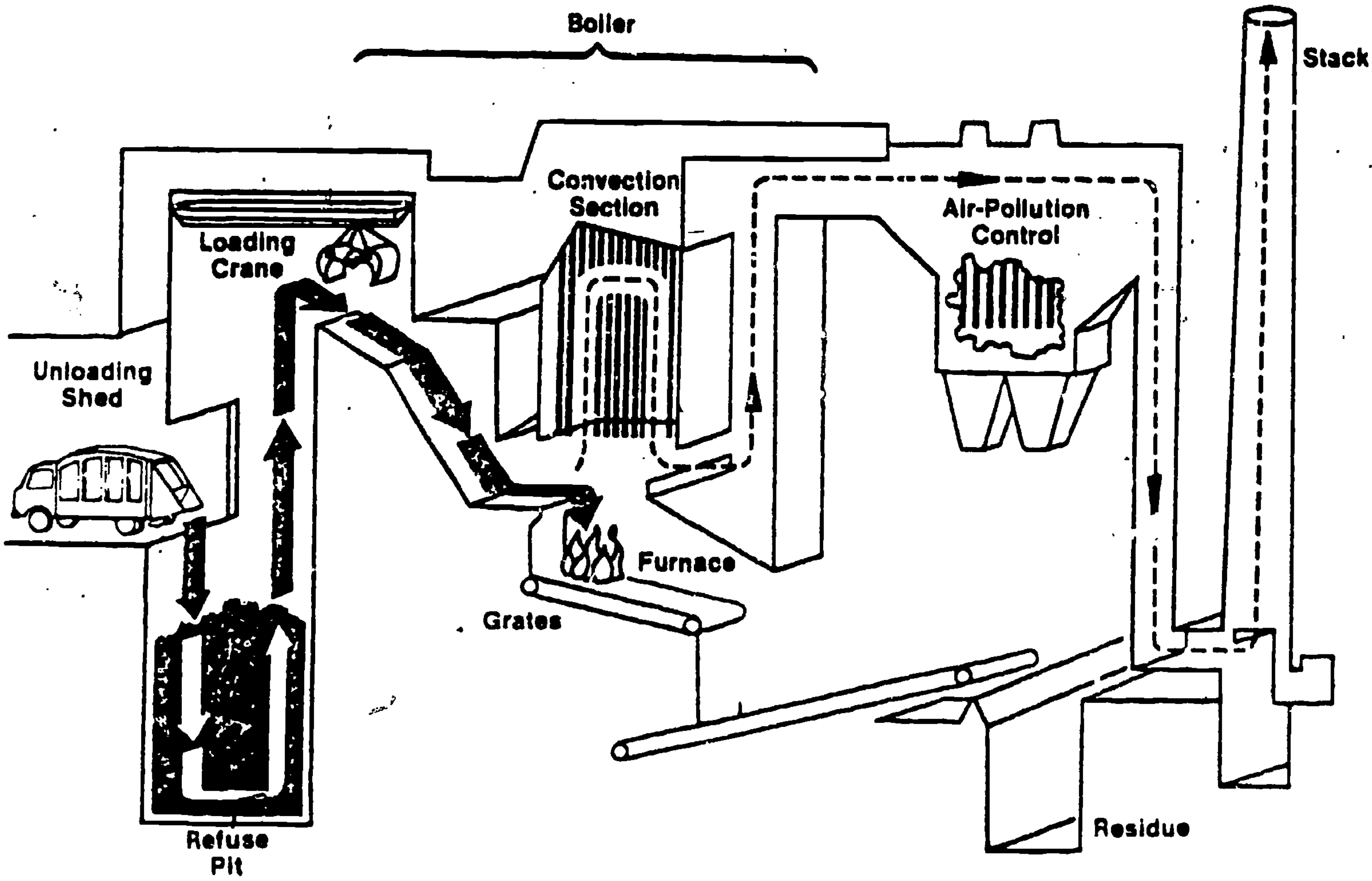
In some installations shredding to reduce waste size and/or facilitate recovery of materials take place. Large bulky items have been shredded before burning. Ferrous metal can be removed by magnetic separation before or after incineration.

Waterfall combustion systems have been used commercially in Western Europe since World War II.

Nashville Thermal Transfer was one of the early systems in this country. The process begins at the waste storage pit where unprocessed solid waste is delivered to the plant in a variety of vehicles. Two overhead cranes change this waste in one ton bites into two waterwall incinerators, each with a rated capacity of 360 tons of refuse per day and a production capacity of approximately 108,000 pounds of steam per hour. The incinerator boilers maintain a temperature of approximately 1800°F and are equipped with reciprocating grates. Steam generated by the boilers leave the plant at 600° and 400 pounds of pressure.

The incinerators achieve approximately 90% volume and 70% weight reduction.

For cooling, steam generated in the boilers is piped into two 7,000 ton steam driven centrifugal refrigerators which are used to chill water to approximately 41°F for use in the distribution system. This system has 15,000 feet of pipe lines in each direction. At present the system is providing service to 29 buildings including 14 state buildings.



WATERFALL FURNACE

Small-Scale Modular Incineration

Small-scale modular incinerators feature heat recovery as steam or hot water and usually forego materials recovery. Most of the applications to date have been in hospitals, schools, and other institutions, and industry whose wastes are more homogeneous.

These systems are called modular because individual furnaces are small and desired plant size is achieved by installing several identical units. MSW is incinerated in two stages. First it is burned in insufficient air to achieve complete combustion, producing a combustible gas and a byproduct residue. The gas from primary combustion is then burned with an auxiliary fuel (oil or gas) in a secondary combustion chamber with xcess air. Hot gases from the secondary combustion chamber are passed through a waste heat recovery boiler or heat exchanger to produce steam, hot water, or hot air. The two-stage combustion process as contrasted to traditional single stage incineration helps to reduce particulate emission problems.

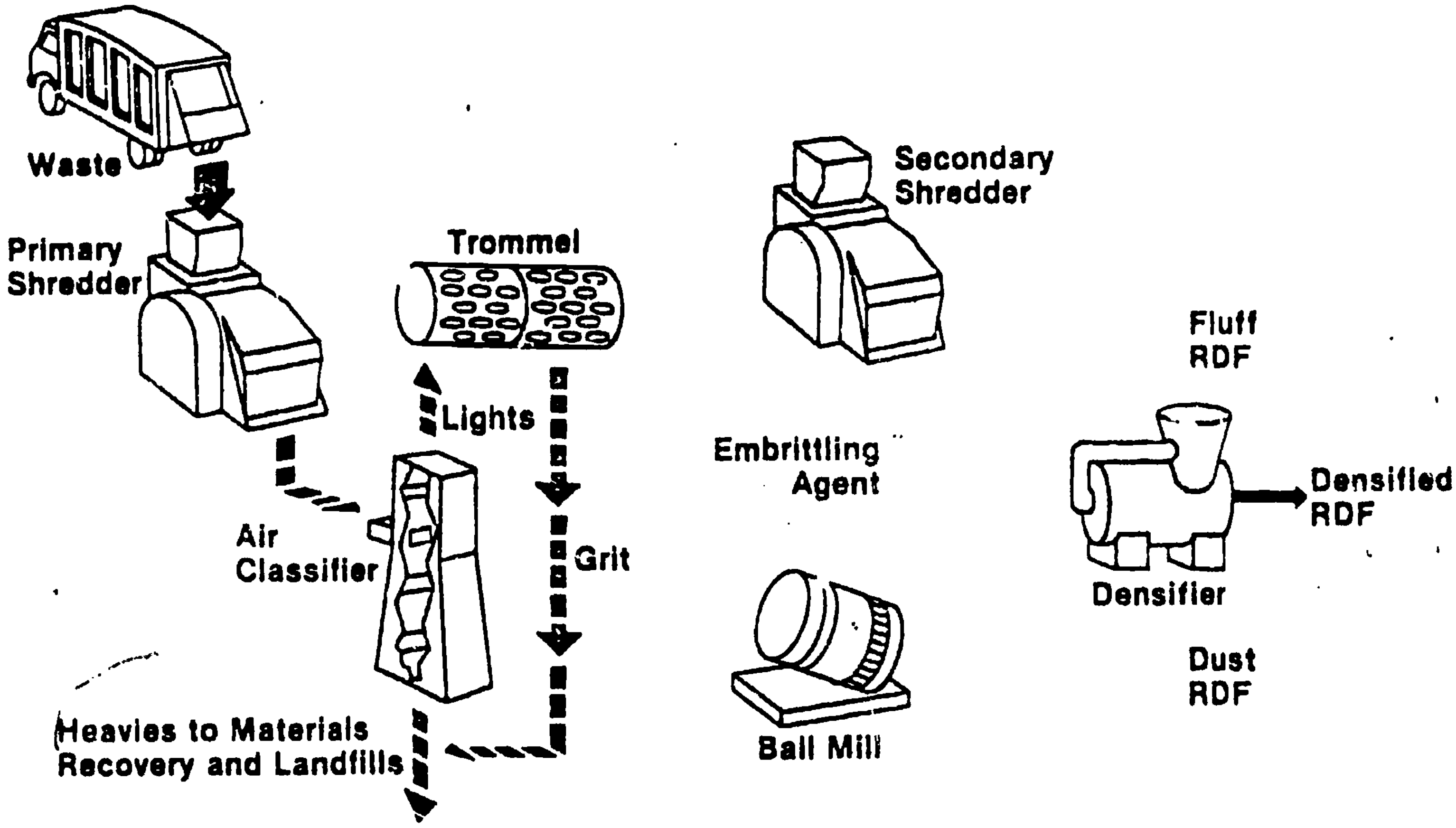
Refuse-Derived Fuel Systems

Solid refuse-derived fuel is produced by separating MSW and mechanically removing the organic combustible fraction using wet or dry processes. The fuel product of dry processing can be fluff refuse-derived fuel (RDF), densified RDF or dust or powdered RDF depending on the processing method used. Most RDF plants recover ferrous, aluminum, glass or mixed nonferrous metals.

In dry mechanical processing, raw waste is first shredded to 8 inches or less in size. This shredded material is next put through a device called an "air classifier" that separates the lighter organic material from metals and other heavy organic and inorganic materials. The light material then goes through a rotating screen or "trommel" to remove sand, glass, and grit. The heavy materials from the air classifies and trommel move to a magnetic separating device that recovers ferrous metals. The light organic material from the trommel goes to a secondary shredder that further reduces the particle size to less than 1½". The result is called "fluff RDF," this can be passed through a pelletizing machine to yield "densified RDF." The objective is to improve storage, handling, and stoker-furnace burning characteristics. The light output from the trommel can be treated with a chemical embrettling agent and ground to a fine powder to produce a "dust or powdered RDF."

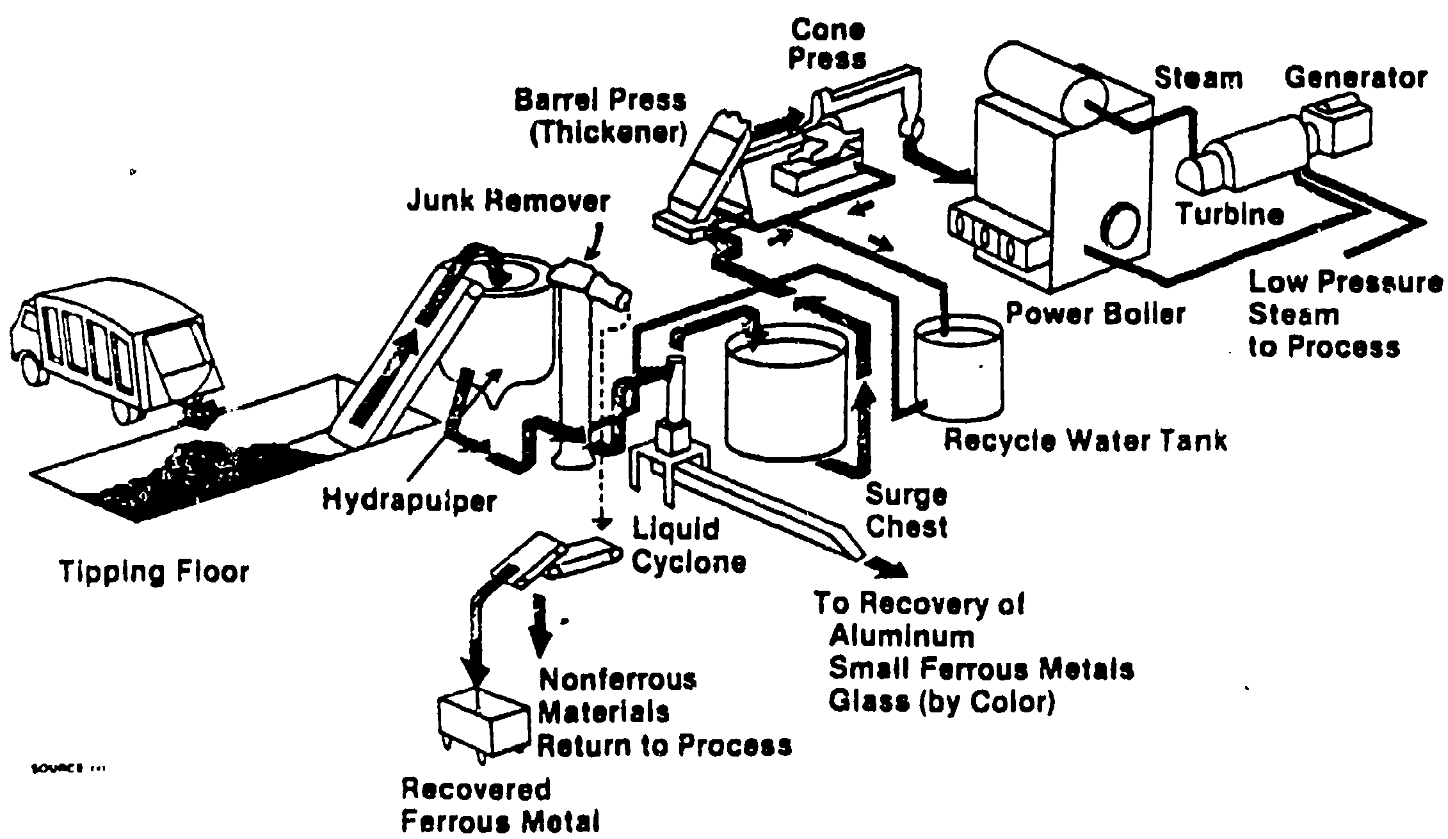
The wet process RDF method raw refuse is fed to a hydropulper where high speed rotating cutters chop the waste in a water suspension. Large items are ejected and the remaining slurry is pumped into a liquid cyclone separator where smaller heavy materials are removed. Water is then removed to leave "wet RDF."

The wet pulping method has several advantages and disadvantages relative to the dry process. Sewage can be mixed with the wet pulp prior to dewatering and the resulting mixture can be burned as a method of co-disposal. The wet process reduces the likelihood of explosion or fire in the size reduction phase. It is possible to recover some organic fiber by the wet process.



DRY PROCESSING

Produces Fluff, Densified, or Dust RDF

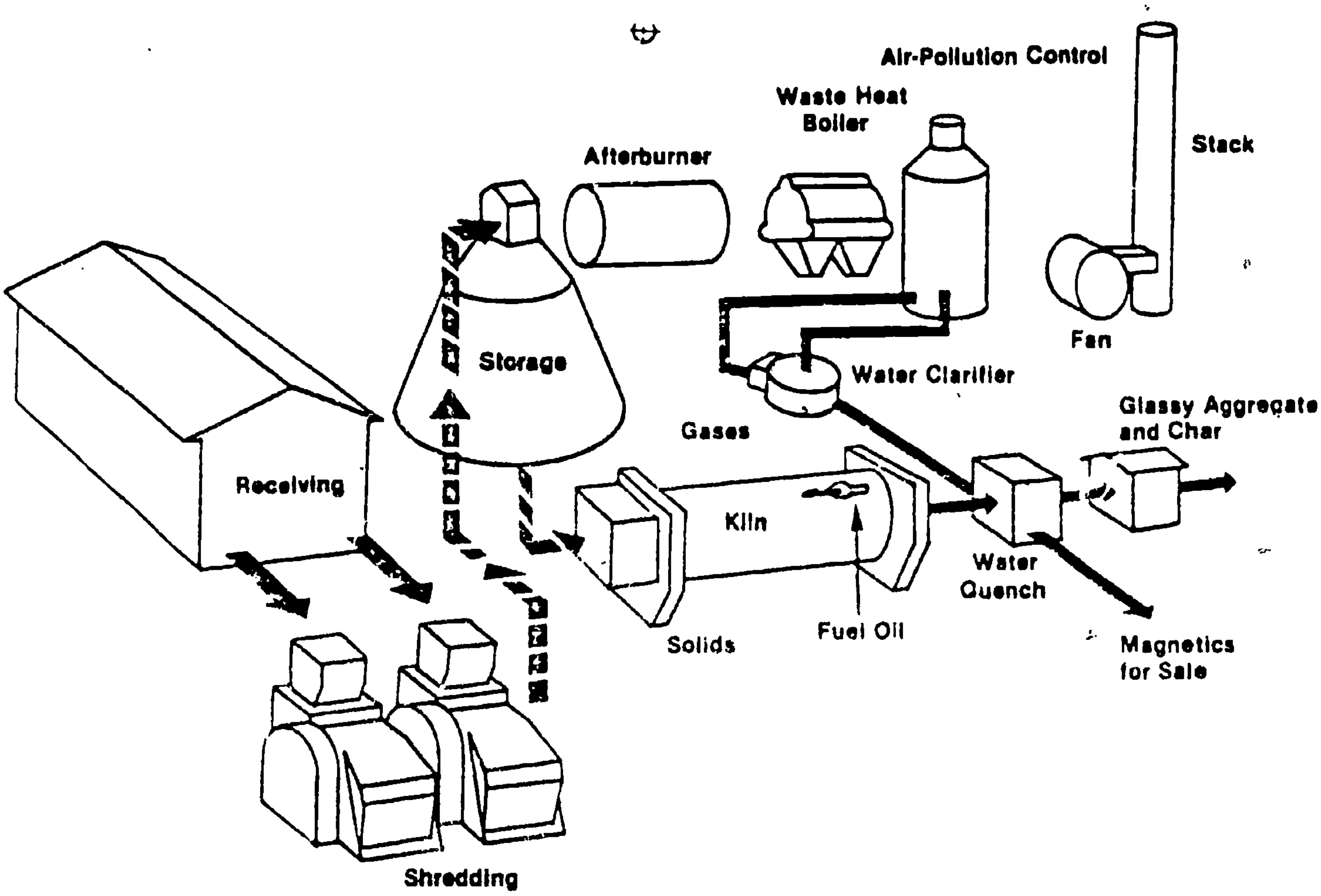


WET PROCESS ENERGY RECOVERY SYSTEM

Pyrolysis Systems

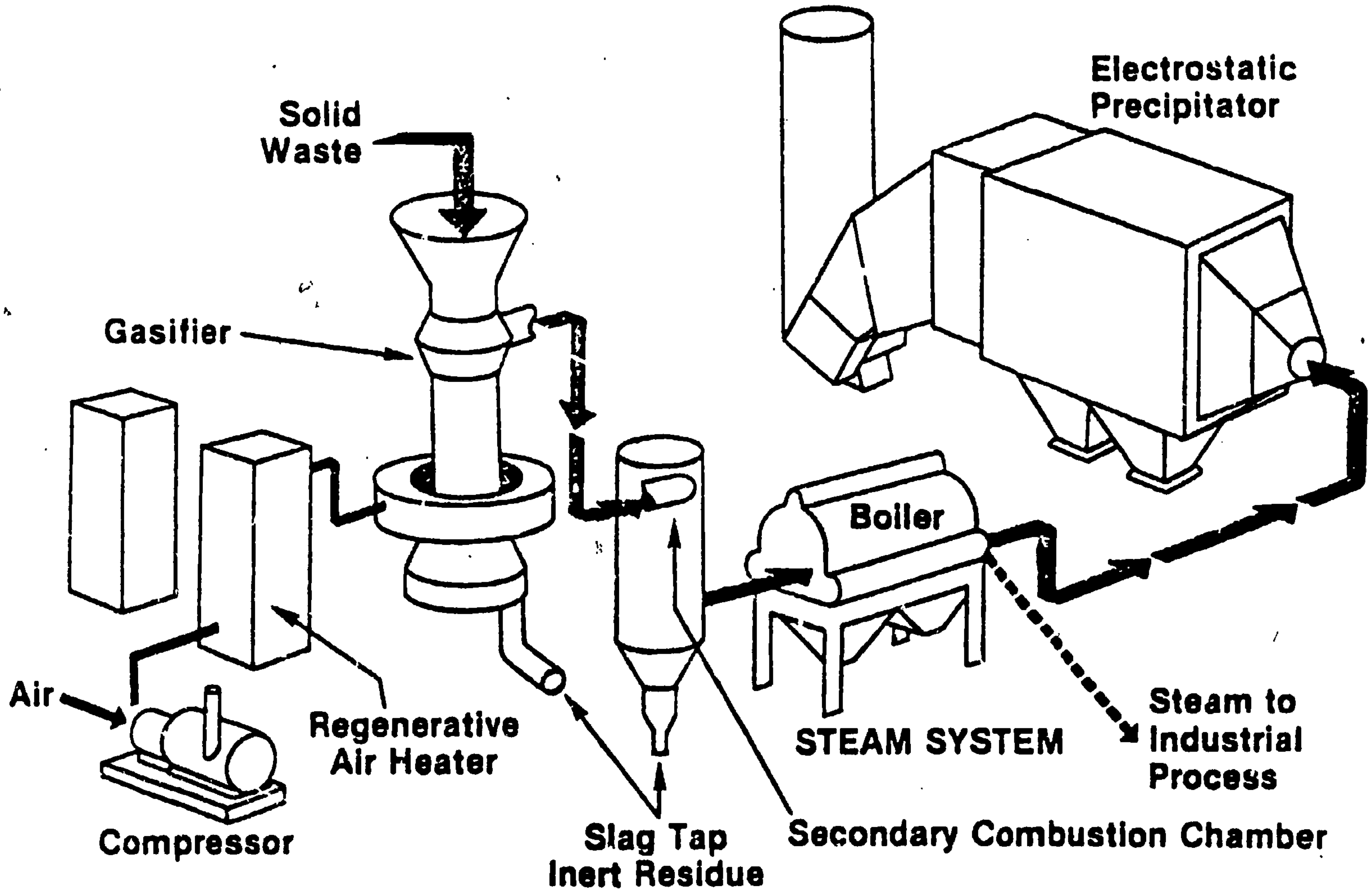
Pyrolysis is destructive distillation or decomposition of organic materials in MSW at elevated temperatures in an oxygen deficient atmosphere. The product of pyrolysis is a complete mixture of combustible gases, liquids and solid residues usable as fuels or chemical raw materials. The characteristics of the pyrolysis products depends on such variables as time in the reactor, process temperature and pressure, oxygen content of the gas in the reactor, particle size of MSW feed, and the choices of catalysts and auxiliary fuels.

Four systems are presently in some stage of demonstration. Two produce low-BTU gas, one produces medium BTU gas and the fourth produces a liquid fuel.

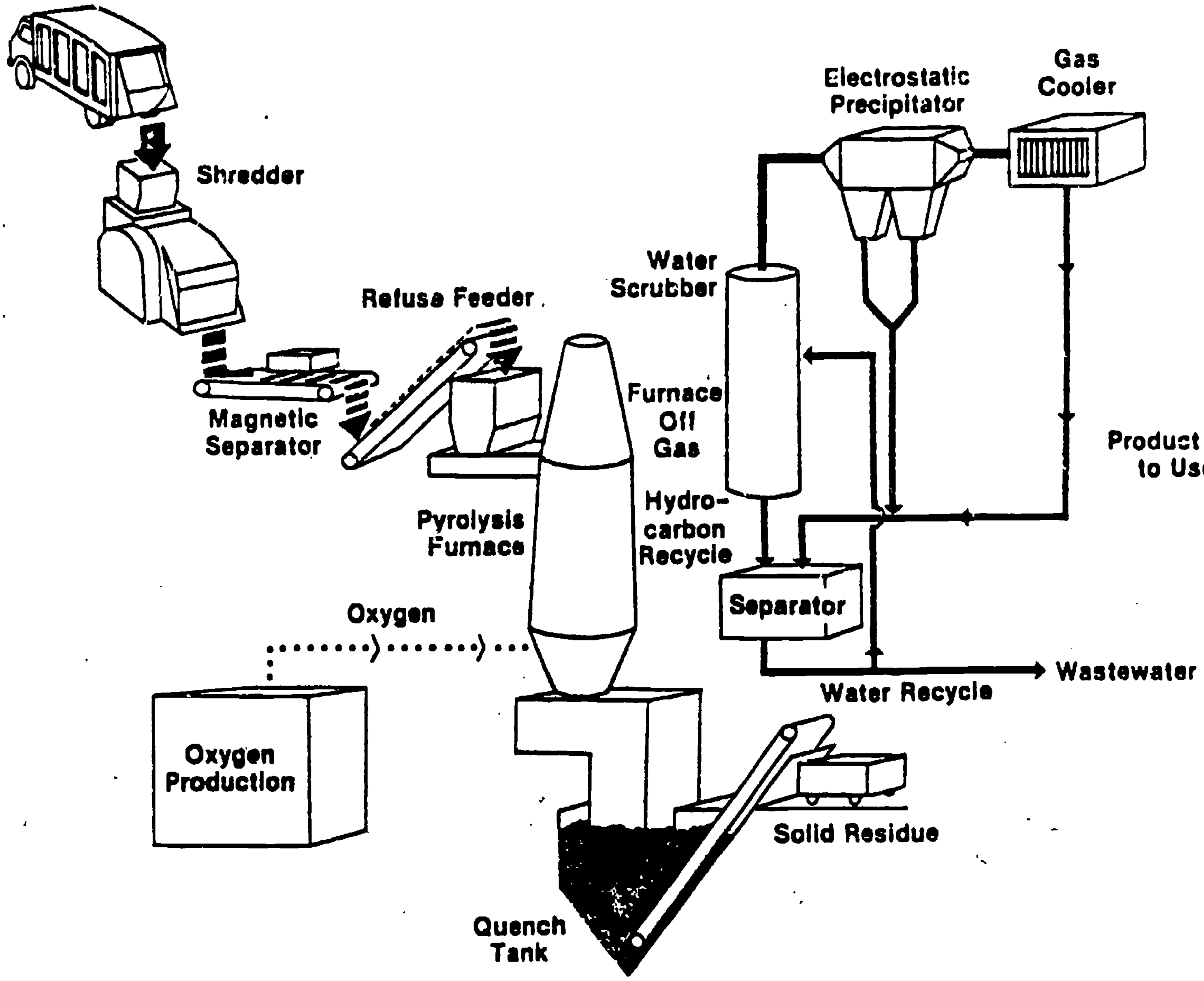


MONSANTO LANDGARD

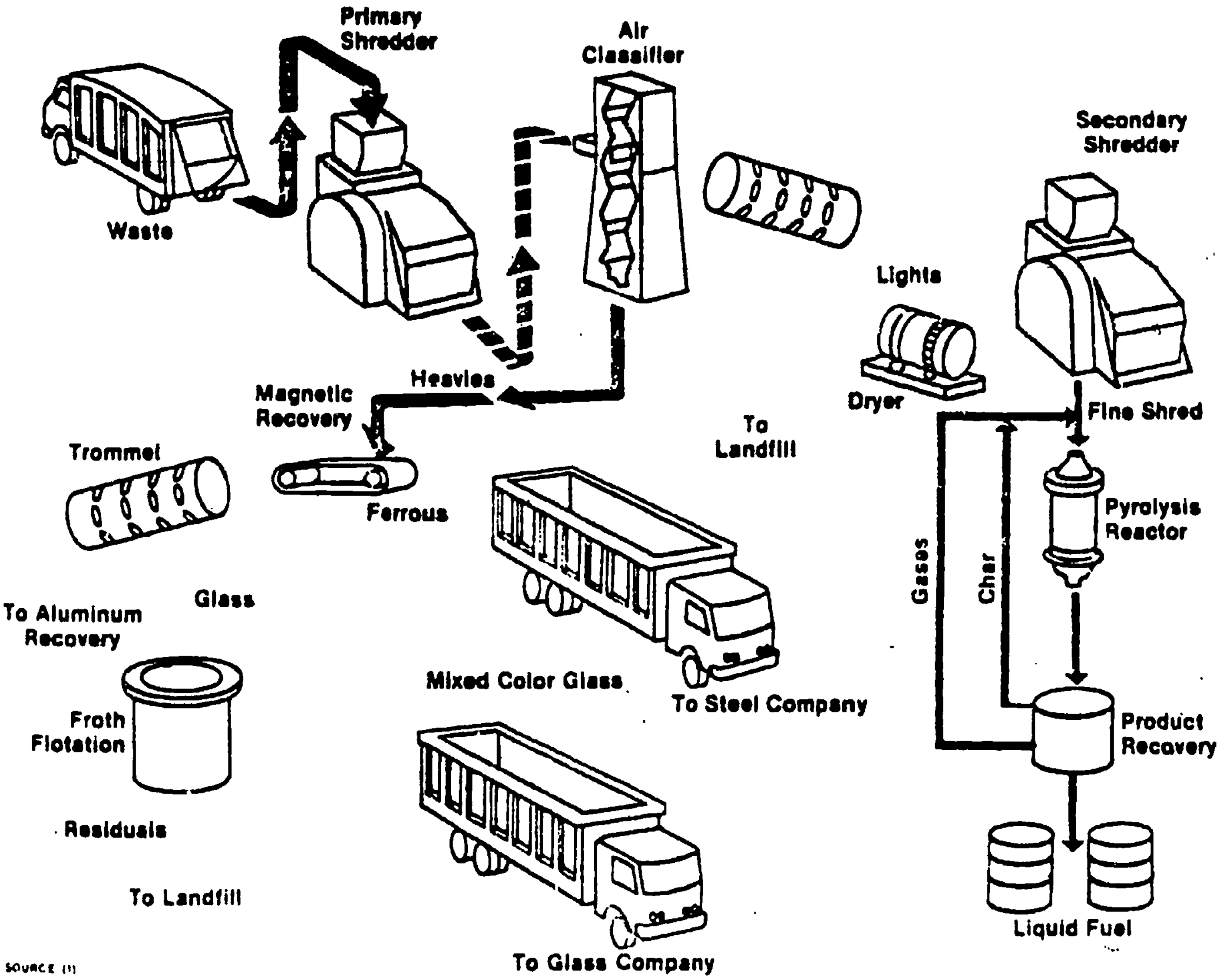
Produces Low BTU Gas
Burned on Site to Produce Steam



TORRAX SLAGGING PYROLYSIS SYSTEM



MEDIUM BTU GAS FOR SALE



LIQUID FUEL FROM SOLID WASTE

Biological Systems

This description focuses on three hiological waste-to-energy technologies, recovery of methane from landfills, anaerobic digestion, and hydrolysis.

Methane Production from Landfills

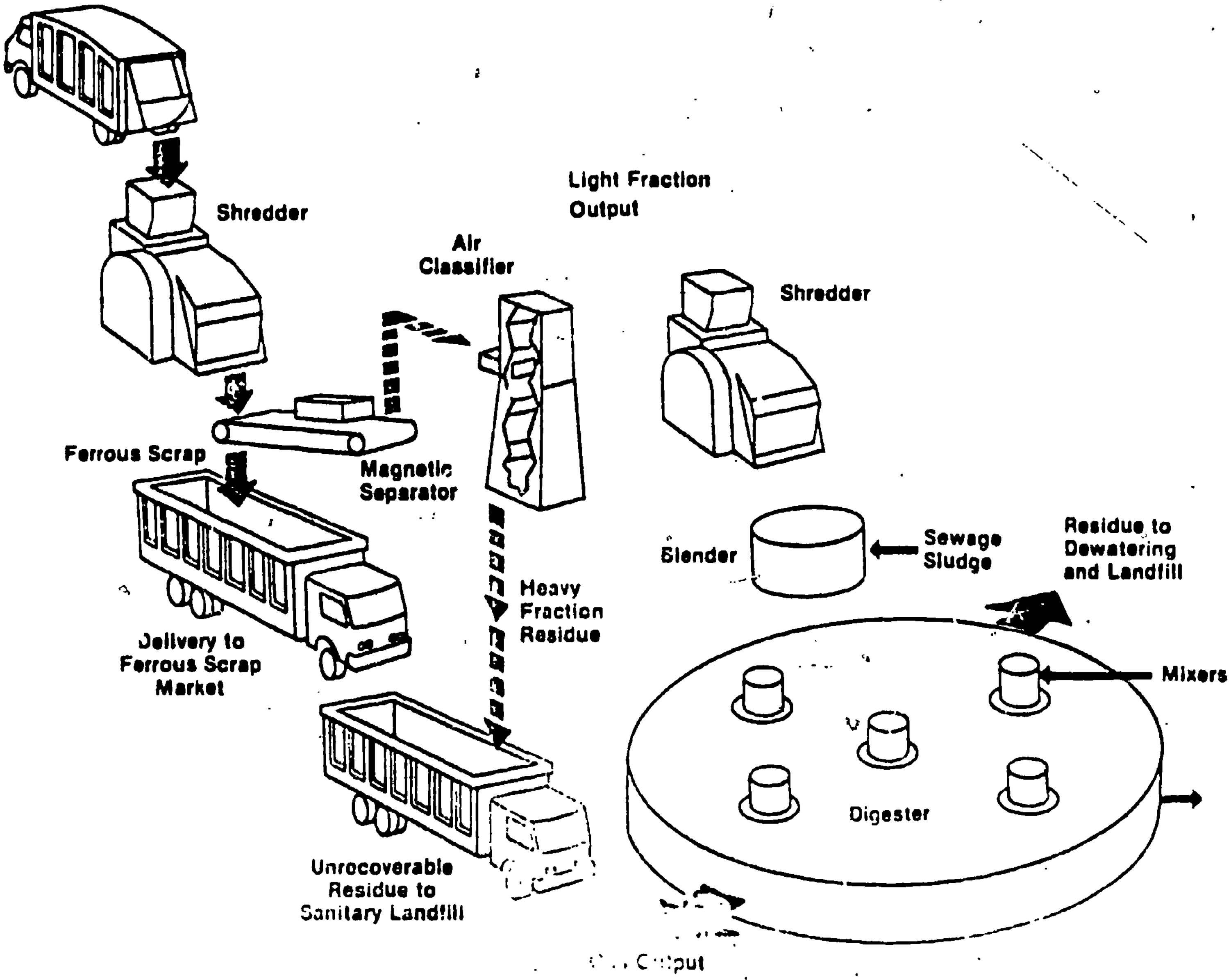
Natural decomposition of MSW in landfills produces a gas composed of roughly 50% methane and 50% carbon dioxide. Gas can be withdrawn through wells drilled into the landfill and can be treated to remove moisture hydrogen sulfide and other contaminants. Carbon dioxide can be removed leaving pipeline quality methane. In some sites 500,000 cubic feet of purified methane is being recovered per day enough to furnish the needs of 2,500 homes.

Anaerobic Digestion

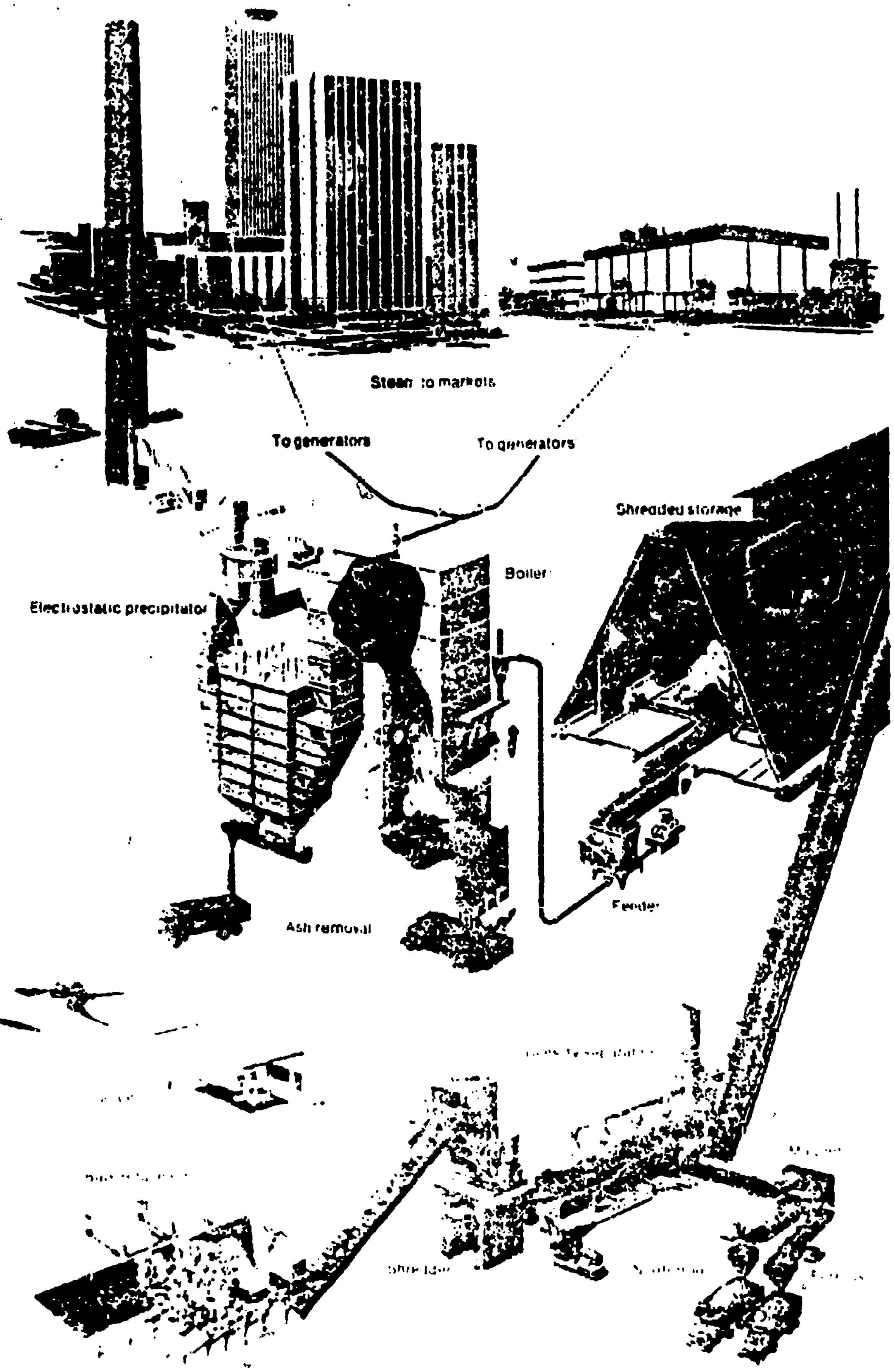
Methane can be recovered from anaerobic digestion of MSW in large tanks or reactors. Anaerobic digestion of waste is accomplished in two ways by bacteria: acid formers that convert waste to organic acids, and methane producers that convert the acids to carbon dioxide methane. One of the problems with methane generation is that MSW sometimes contains toxic components that can kill the methane producing bacteria.

Hydrolysis

There are two processes for the production of ethyl alchol from the organic portion of MSW by hydrolysis: acid hydrolysis, which is a well-developed industrial technology for non-waste applications and enzyme hydrolysis.



BIOLOGICAL GASIFICATION OF SOLID WASTE


Steam to markets
To generators
To generators
Shredded storage
Boiler
Electrostatic precipitator
Ash removal
Feeder

BEST COPY

Materials Recovery Systems

Aluminum

The process for aluminum recovery is based on an eddy current separation system commonly called an aluminum magnet. With this technology, nonferrous conducting metals mixed with other wastes are conveyed through a magnetic field in such a way that an eddy current is induced in the metals. This current causes the metallic conductors to be repelled from the region of the magnetic field and thus out of the conveyor path. Nonmetalics are unaffected and are carried on. The device is quite sensitive and can be tuned to repel various shapes, densities, or materials. For example, it can be tuned, or optimized, to recover aluminum cans, the largest part of the aluminum waste. As of April 1978, none of these facilities was in steady production with a sustained commercial run.

Electrostatic separation is another method of separating nonferrous metals from organic materials. Mixed wastes pass between charged plates and are given an electric charge. Conducting materials such as aluminum lose their charge on an electrically grounded drum and fall off. Nonconductors retain their electrical charge and adhere to the drum. None of these systems is in use in full-scale plants. To further assist in cleaning contaminants from metals, a device called an "air knife" if sometimes used.

Glass

Two systems are being experimented with for the recovery of waste glass from MSW. Research is proceding on froth flotation, a standard mineral processing technique, for the recovery of glass. In this process the "heavy" portion of the waste stream, rich in finely ground glass, is slurried in water along with chemicals that cause the glass to become attached to air bubbles on the surface of the water. The glass floats out of the mix with the bubbles and is then washed and dried. Since glass recovered by froth flotation produces mixed colored cullet, which has a limited market, the process of "optical sorting" is being examined. Glass particles around one-fourth inch in size, are sorted, on the basis of their light transmission properties into three colors, clear (flint), green, and amber. This process currently faces problems with high costs and its inability to reject a sufficiently large fraction of contaired ceramics and stones to meet the quality standards required by glass producers. It also cannot recover particles smaller than one-fourth inch in size.

Ferrous Metals

Ferrous metals have been removed from MSW by magnetic separators for a number of years. A recent study by the American Iron and Steel Institute identified nearly 40 such commercial installations in the United States. Some experience has been gained more recently in magnetic recovery of incinerated ferrous metals from the residue or ash from MSW incinerators. The recovered ferrous material is not currently being marketed. The U.S. Bureau of Mines has experimented with a complex mineral-technology-based process for "back-end" recovery of a variety of materials from incinerator residue. Incinerated ferrous may be less marketable than the unincinerated product.

Compost

Composting permits organic matter to decay to humus, which can be used for fertilizer or soil conditioner. Generally, composting has not been economically successful because of difficulty in selling the humus product. According to EPA, only one composting plant was operating as a commercial facility in 1976, the 50-tpd plant at Altoona, Pa. A 1969 survey identified 18 plants with a total capacity of 2,250 tpd, indicating a major decline in U.S. composting operations in this 7-year period.

Composting is successful in some European countries. In the Netherlands where markets for humus in the flower and bulb industries are good, the Government runs composting operations. A technique for briquetting and joint composting of MSW and sewage sludge has been developed in Germany. It's developers claim that the dried briquets can be used in food for pigs, as a soil conditioner, as a stable element in landfills, or as fuel.

Fiber

Not many centralized resource recovery facilities can reclaim fiber from MSW for recycling as fiber. A 150-tpd demonstration fiber recovery facility has been operating since 1971 at Franklin, Ohio, using the Black Clawson wet process described earlier. Fiber recovered with this process is of poor quality, and it is sold to a nearby manufacturer of asphalt-impregnated roofing shingles Two wet process plants, the Hempstead, N.Y., facility now under construction, and the plant in Dade County, Fla., about to begin construction, will recover the fiber for use as a fuel, not for paper production.

A dry process for recovering paper fiber and light plastics has been developed by the Cecchini Company in Rome, Italy. Paper from this process is used with straw to make a low-grade paperboard. In general, the quality of the recovered paper is low and it has limited marketability. Roughly 23% of the paper in the input waste stream is recovered. Other dry paper recovery processes, such as the Flakt process, which are being explored on a pilot plant basis in Western Europe, are described by Alter.

Finally, some of the most recent plants (Milwaukee and New Orleans) feature limited paper recovery by hand-packing of bundled paper from the resource recovery plant input conveyor. This method has both economic and quality limitations.

IV. Economics

In the cost-benefit analysis into the construction of a Municipal Solid Waste (MSW) facility, an indepth study should be undertaken to evaluate the net cost and assests of such a plant. The study should center around the concept that as you are converting waste to energy, you are potentially solving two problems that we live with today: our energy sources and the many headaches associated with the storage of solid waste in landfills. The governing body of the impact area should involve all local public officials, engineers, and intergovernmental advisors into the study of the MSW plant. After much study has been completed, and facts and figures are analyzed, it would then be recommendable to inform the involved public as to the safety and economic impact of such a facility.

Some MSW plants that have had proper study and planning have been a tremendous success for the community since it heats and cools nearby industrial buildings and some plants even produce electricity which can be sold to the TVA. Other plants have been a complete disaster due to a lack of proper planning of the available resources.

The evaluative study should compare the cost and benefits to be derived from a MSW plant--landfill relationship for energy production and waste storage as opposed to the cost and benefits from only a landfill for the storage of the biomass, and other waste products from the study area.

In considering such a facility much cost is involved, but there are benefits to be derived also. Below I will briefly list the major cost involved in the study, construction, and operation of a MSW plant, and then list the benefits to be derived.

Cost:

1. Engineering and planning cost
2. Purchase of a building site
3. Actual construction of the plant and its equipment
4. Labor and maintenance
5. Waste pick-up and disposal
6. Auxillary fuels

Most of the cost will come from the construction of the plant and purchase of its operating facilities. Such financing may be made available over an extended period of time through bonds, user fees, federal grants, and loans and tax revenues. The labor force to operate most facilities of this nature seldom exceed 30. Cost due to maintenance is minimal, but must be considered due to the extremely high temperatures encountered inside the furnaces. The waste pick-up cost would almost be negligible since it would have to be picked up and carried to the dump site anyway. It must be pointed out here, however, that the garbage and biomass volume has been reduced by approximately 90% and weight reduced by 70% after burning.

Benefits:

1. Sale of energy and ferrous materials
2. The number of land-fills to be purchased and maintained are held to a minimum
3. Reduced water and air pollution
4. Reduces the cost to collectors of dumping in controlled environments.

The sale of energy is probably the second biggest benefit. Even though it cost approximately $3.00/ton to put waste in the ground as opposed to $20.00/ton to burn, the energy production must be realized.

With the price of energy from hydroelectric dams, nuclear reactors, petroleum, etc., spiraling upwards, it seems apparently clear that the energy from thermal plants will tend to become much cheaper than from these sources. Energy produced today from MSW plants and from the other energy sources are proving this point. Let us look at an example that will illustrate this fact. The thermas plant in Nashville, Tennessee can handle 400 tons of garbage each day and can burn the garbage at approximately $20.00/ton. In order for the plant to supply the same number of customers the same amount of energy with natural gas would cost $800.00/hr. A little multiplication shows a tremendous savings to these customers to heat and cool their buildings from the thermal plant.

Probably the chief benefit to be derived from burning the garbage and biomass would be the reduction in the amount and nature of the waste to be carried to the land fill. Land fill sites have to meet very strict health and environmental codes and real estate is very expensive. Since burning the garbage would reduce the volume by approximately 90%, much less land would have to be made available for garbage disposal and the infiltration of toxic waste into the water supply and air to the population near the dumps and land fills.

This waste is what we're now having trouble removing from our environment. Since this waste has impressive potential energy, it only seems logical to burn it, use the energy released from the burning process and then dump the much reduced amount of solid waste. It has been estimated that the biomass wood available in the U.S. timberlands could yield 3 million barrels of oil/day in energy equivalent.

A noneconomic but important advantage concerning the burning of biomass fuels over fossil fuels is that in growing, biomass absorbs enough CO_2 to roughly balance the carbon emitted in burning the fuels.

From most studies and implimentations, a Municipal Solid Waste Thermal Plant proves to be a sound economical investment since it is helping to solve two problems--our land fill problems and our dependence upon very expensive energy.

STUDENT ACTIVITIES

1. Make an "energy use" study of your home. Identify where energy is used and how much. Develop ways to conserve energy.

2. Investigate one form of energy; it's long-term strengths and weaknesses, and it's effects on the local community, state, and nation.

3. Explore and report on probable consequences of a long term fuel shortage on these areas and industries: food, clothing, and textiles, cosmetics, plastics, household.

4. Create a one-minute radio or television commercial dealing with some aspect of energy conservation.

5. Estimate the minimum amount of energy you would need for bare existence for one week (NASA-Energy: Alternative Program 7)

TIME ALLOTMENT--Five working class days

Days — Type of Presentation

1---Introduction and assignment of student activities.

2---Vocabulary

3---Slide PRESENTATION OF DESIGN, OPERATION AND ECONOMICS

4---Puzzle, and test review

5---Test

ENERGY PUZZLE

F	S	C	L	Y	G	R	E	N	E	B	A	T
E	O	P	A	E	F	D	N	I	W	Z	N	T
S	G	M	M	R	A	E	L	C	U	N	O	E
M	E	R	V	O	R	L	M	D	S	B	I	M
X	O	Q	E	N	B	R	I	L	S	M	T	Y
Y	M	E	H	V	I	A	A	O	A	W	A	K
P	A	L	T	M	A	B	C	L	M	I	V	A
Z	E	A	O	P	W	W	L	A	O	C	R	U
H	T	H	E	R	M	A	L	Z	I	S	E	E
L	S	S	G	L	E	N	E	R	B	E	S	R
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H	N	O	I	S	U	F	H	C	O	A	O	D
O	S	L	L	E	C	L	E	U	F	C	C	S
O	P	E	O	P	L	E	S	K	L	P	Q	X
C	I	A	T	L	O	V	O	T	O	H	P	Z

BIOMASS	ENERGY
THERMAL	SHALE
SOLAR	WIND
NUCLEAR	WAVE
COAL	FUSION
GEOTHERMAL	OIL
STEAM	FUEL CELLS
CONSERVATION	ELECTRICAL
PHOTOVOLTAIC	

DIRECTIONS: Find the above words in the square and circle.

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U.S. Department of Energy. "Biomass Energy Bulletin." Oak Ridge, Tennessee, November 1980.

AUDIO VISUAL MATERIAL

Solid Waste Disposal Filmstrip Program
FS-383-D to filmstrips/cassettes and teacher's guide $48.00 obtained from
Crystal Productions Materials Catalog 1981,
Box 12317
Aspen, Colorado 81612

Personal Slide Presentation of Nashville Thermal Plant
(Obtained from Tour of Plant)