INDUSTRIAL WASTE UTILIZATION
A STATE-OF-THE-ART REVIEW

by

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The quantity of industrial wastes generated in the United States annually has been estimated to exceed 90.7 million metric tons (100 million U.S. tons), with a heat content of more than a quadrillion BTU. Utilization of a portion of these wastes in one way or another does not represent a new concept. Industry has generally been cognizant of the economics associated with byproduct streams and scrip which, if discarded, are a liability. However, if they can put to use, they can be converted to assets. Let's review for a moment some of the more common means of disposing of industrial wastes.

Recycling (Figure 1) might be considered the most desirable method for disposing of industrial waste streams. Not only is the waste stream eliminated but the raw material demand is reduced and the energy which would have been expended to procure, pre-process, and transport the additional raw material is saved. This first table (Figure 2) shows a list [1] of published values of the energy required to produce various materials.

Some scrap can be reworked with minor preparation. For instance the edge trimmings and off-quality product from a paper drying machine can be redissolved, mixed with fresh stock, and redried. However, a tire casing mistake does not lend itself readily to recycling. Likewise, byproduct streams frequently contain substances which have been deliberately removed and thus cannot be recycled. As an alternative to recycling, many byproduct streams (Figure 3) can be sold at a profit. Sometimes it takes a little vision and ingenuity to develop a market or to convert the waste to a salable form.

Burning (Figure 4), without heat recovery, provides a means of disposing of a variety of wastes. Recycling and byproduct recovery are limited to identifiable streams consisting of, or containing, usable materials. Any waste stream which contains combustible material is a candidate for recovering heat (Figure 5). The triangular graph shown in [2] this first figure (Figure 6) defines the composition limits for combustibles, water, and non-combustibles other than water which are necessary for autogenous combustion in a conventional furnace. Wastes falling outside these limits can sometimes be processed to bring them within limits. For example, pulp mill spent liquors, which are burned to recover the heat in the organic portion and, in some instances, to recover the inorganic chemicals for reuse, must first be concentrated by the evaporation of excess water.

Table II (Figure 7a, 7b) [3,4,5,6] lists some of the more common industrial wastes with their approximate heating values. The decision to recycle, sell, or burn as opposed to disposal by landfill, sewering, or venting (Figure 8) is basically a matter of economics and awareness.

The economic considerations governing the method of disposal of industrial wastes can be discussed here only in general terms, since the cost of disposal, by whatever method, is very much a function of local conditions. However, we can list some of the points which must be considered when evaluating each method of disposal.

- Recycling (Figure 9)
  - (1) Product quality--can the recycled material be used without adverse effects?
  - (2) Technology--do we know how to process the recycled material, or is a development program required?
  - (3) New problems--what new waste streams are created in the recycling process? How do we dispose of them?
  - (4) Reliability--can we depend on the recycle stream as a regular source of raw material? What is the effect on raw material inventory? on raw material purchasing contracts?

- Selling as a byproduct (Figure 10)
  - (1) Marketability--is there an existing market, or can we create one?
  - (2) Technology--is processing necessary? Do we know how to achieve an acceptable quality? What are the specifications which the byproduct must meet?
  - (3) New problems--what new waste streams are created in processing the byproduct?

- Burning (Figure 11)
  - (1) Heat recovery--can we use the energy released by burning the waste? Can it be used to generate steam or power or to provide heat to a process? Can it be burned in an existing facility?
  - (2) Technology--what, if any, preparation or conditioning is needed prior to burning? Will it create deposits on heat transfer surfaces? Will it cause corrosion in any part of the system? What will be the synergistic effect if burned in conjunction with other fuels? Can it be burned safely? Is an R&D program necessary to evaluate its potential as a fuel?
  - (3) Residual ash--is there a use for it? What type of collecting and handling facilities are needed? If not usable, what methods of disposal are possible? What are the ecological implications?

(4) Products of combustion--will particulate collection and/ or removal of gaseous compounds be necessary to meet ambient of NSPS air standards? Is there an acid dewpoint which sets a lower limit on flue gas temperature? Will there be an odor problem?
(5) Reliability--what will be the effect on overall plant reliability if the waste provides a significant portion of the total fuel requirement of the plant?
(6) Purchased fuel--what will be the effect on purchased fuel contracts, fuel inventory requirements, etc. if heat is recovered from waste?

Disposal by landfill, sewering, or venting (Figure 12)
(1) Environmental constraints--what codes and regulations apply to the waste material under consideration? Is it toxic, explosive, odorous, chemically active? What facilities will be needed to process the waste? What monitoring equipment is required?
(2) Collection and storage--what facilities are required to collect, store, and load out the waste?
(3) Removal from the site--will there be hauling costs?

In the days of cheap, abundant fossil fuels, low cost electric power, and few environmental restrictions, there frequently was no economic incentive to utilize wastes. Today, however, with decreasing fuel availability and rising costs of fuel, electrical power and raw materials, many wastes which were discarded in the past may now look attractive as an energy source and/or as a material source. It is important to try to take into account the probable future availability and costs of purchased fuel and power when evaluating a waste stream for energy recovery. The environmental limitations can work both ways. It is no longer permissible to discard many industrial wastes without some form of treatment. On the other hand, burning of wastes, with or without energy recovery, can create atmospheric pollution problems which are expensive and sometimes technically difficult to overcome.

We said previously that the choice of waste disposal methods was a matter of economics and awareness. These probably should have been stated in reverse order, since an awareness of the potential for utilization must precede a study of the economics. Hopefully, the papers being presented this morning and the discussions which follow will provide at least some degree of cross-pollination. It always helps to know what others are doing. Consider, for example, the listing in Table III (Figure 13a, 13b) which shows some of the waste utilization techniques being employed by one diversified manufacturer. It is interesting to note that the combined heat recovered from bark and spent liquors can generate 75-80 percent of the steam required at pulp mills. A number of informative papers were presented in Boston in May at the 1976 National Waste Processing Conference describing a variety of waste utilization techniques and identifying numerous associated problems.

Two novel approaches to industrial waste collection and utilization should be mentioned here. The Union Electric Company in St. Louis has surveyed industries in the surrounding area and received replies from over 500 which have combustible wastes for disposal. Union Electric plans to classify the wastes for burning properties and safety hazards and burn them when possible to supplement their municipal refuse burning operation and reduce their fossil fuel usage. The second operation also in the St. Louis area, is the service provided by the St. Louis Industrial Waste Exchange, operated by the St. Louis Regional Commerce and Growth Association. The Exchange publishes two listings (Figure 14), a Type "A" listing of materials available and a Type "W" listing of materials wanted. Each listing includes a description of the item, composition, quantity, and geographic location. The Exchange puts potential suppliers and users in contact with each other, after which the negotiations are carried out between the interested companies.

For those companies producing hazardous wastes which cannot be handled in-plant, the Federal EPA publishes a pamphlet entitled, "Hazardous Waste Management Facilities in the United States". This provides a listing, by states, of hazardous waste disposal facilities. The listing describes, for each installation, the services offered, wastes handled, wastes excluded, type of processing, and ultimate disposal method. Some of the facilities provide material reclamation/recovery capability, but none appear to provide any heat recovery.

When the potential for energy savings by combustion of wastes is being evaluated in the framework of present and predicted future fuel costs, power costs, and environmental controls, alternate approaches in addition to conventional burning should be considered. Fluidized bed combustion offers the potential for burning a waste containing more than 50 percent moisture (the upper limit indicated in the previous triangular slide). Some typical industrial wastes which can be handled in a fluidized bed are listed by Copeland (Figure 15). [7]

For a plant having a large power requirement relative to its steam demand, it might be desirable to employ a combined cycle (Figure 16). This figure shows one approach using a gasifier, gas turbine, waste heat boiler, and back-pressure steam turbine to provide both power and steam from the waste stream. However, gasification by pyrolysis and the utilization of those gases in gas turbines is not yet an established process, nor has the economic justification been demonstrated.

Our objective this morning is to generate information on new ways, or potential ways, to convert industrial wastes into assets and to identify the associated problems. Some of these problems will lead to a definition of research needs. I have attempted here to cover some of the general considerations. The four papers to follow will discuss some specifics in more detail.

REFERENCES

(1) Hill, Christopher T. and Teasley, Larry N. Energy Implications of Plastics Production and Utilization, paper presented at First Annual AIChE Southwestern Ohio Conference on Energy and Environment, Oct. 25-26, 1973.

(2) Papamarcos, John, Power From Solid Waste, Power Engineering, Sept, 1974, p 48.

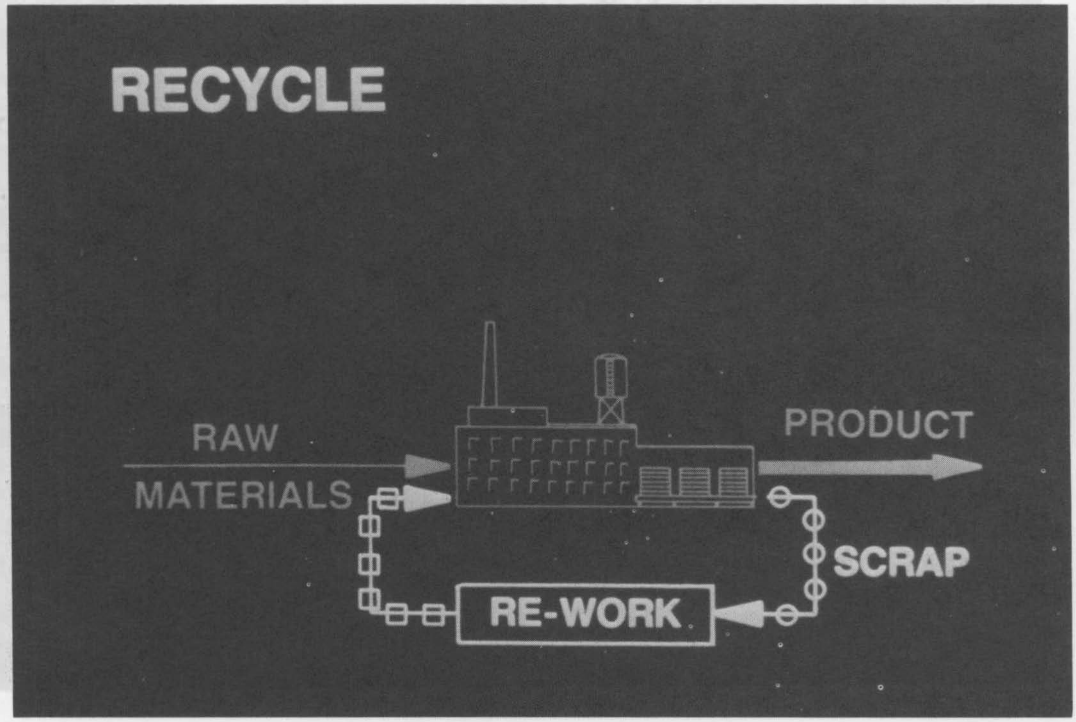
(3) Energy Conservation Waste Utilization Research and Development Plan, Mitre Technical Report MIR-3063, July, 1975, p 43.

(4) Fernandes, J. H., and Shenk, R. C. , Solid Waste Fuel Burning in Industry, paper presented at American Power Conference, Chicago, Illinois- April 29-May 1, 1974.

(5) Kaiser, E. R., The Incineration of Bulky Refuse, Proceedings of the 1966 National Incinerator Conference, ASME, New York, N.Y.

(6) Brashears, D. F. and Hughes, A. J., Heat Recovery by Incineration of Refinery Wastes, paper presented at the Petroleum Mechanical Engineering Conference, Los Angeles, CA, Sept. 16-20, 1973. ASME Paper 73- Pet-2.

(7) Copeland, G. G., Disposal of Solid Wastes by Fluidized Bed Combustion, proceedings of the Third International Conference on Fluidized Bed Combustion, Volume I, (Session II, Paper No. 2), Oct. 29-Nov. 1, 1972.

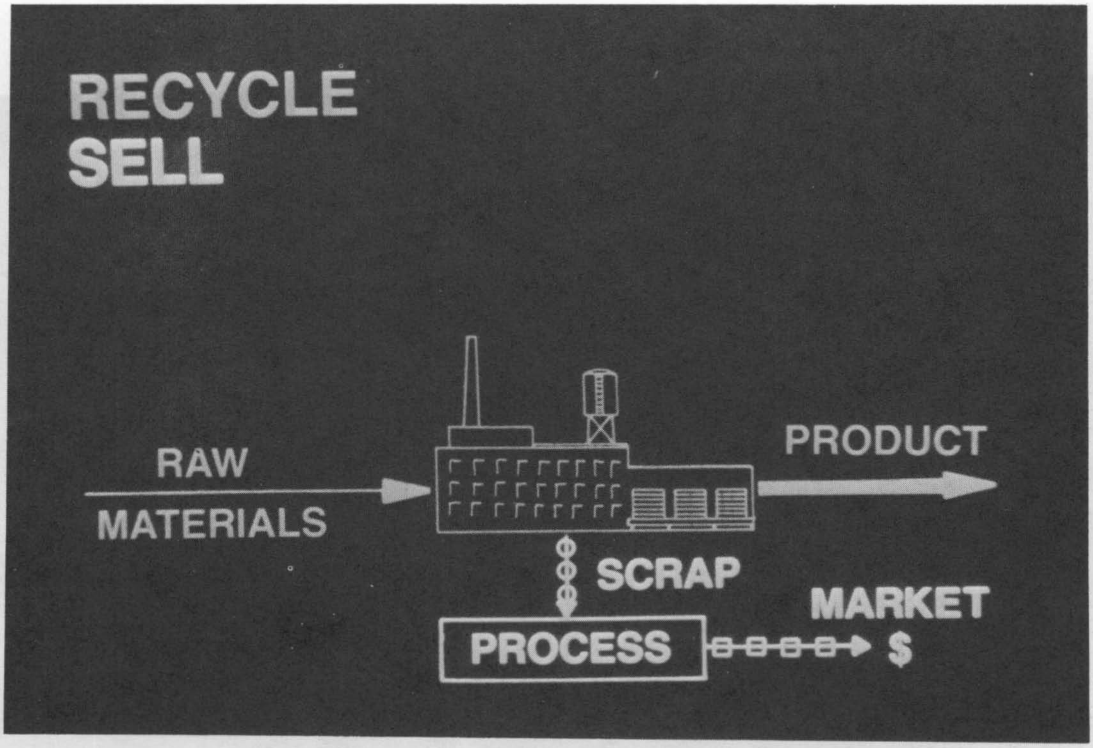


SLIDE 1

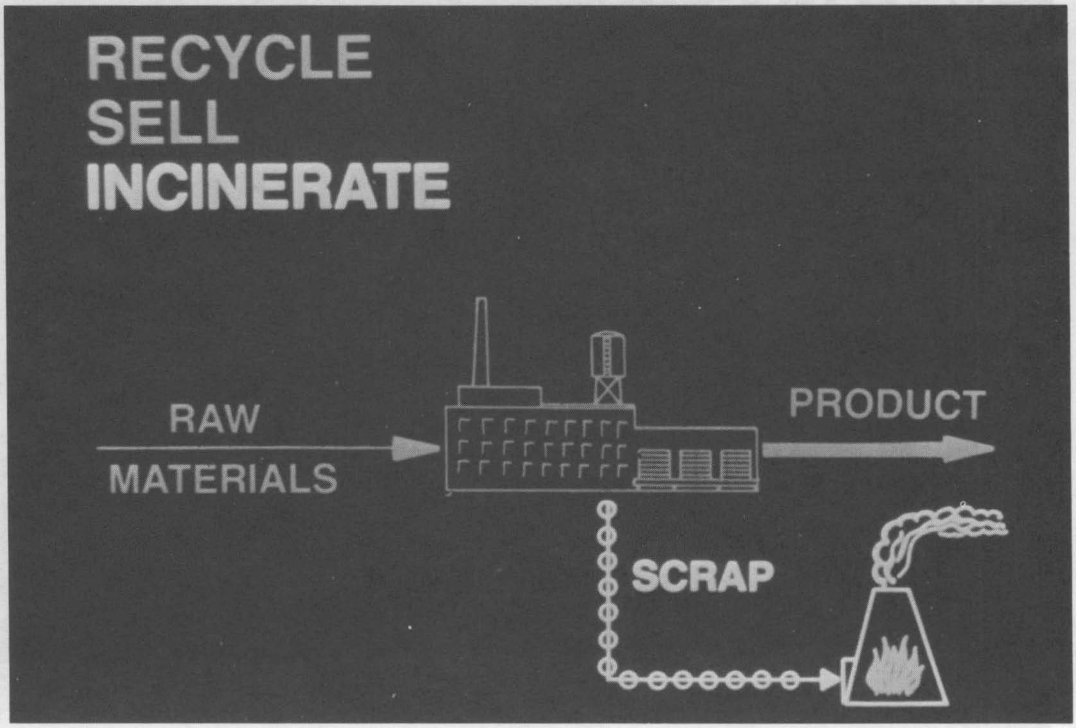
ENERGY REQUIRED TO PRODUCE VARIOUS MATERIALS

Material	Energy (BTU/lb.)
Polystyrene	9,000- 29,000
Polyethylene	12,000- 23,000
Steel	13,000- 25,000
Aluminum	72,000-113,000
Copper	24,000- 53,000
Zinc	24,000- 40,000
Lead	20,000
Titanium	239,000
Glass	7,000- 11,000
Cement	4,000
Paper	10,000

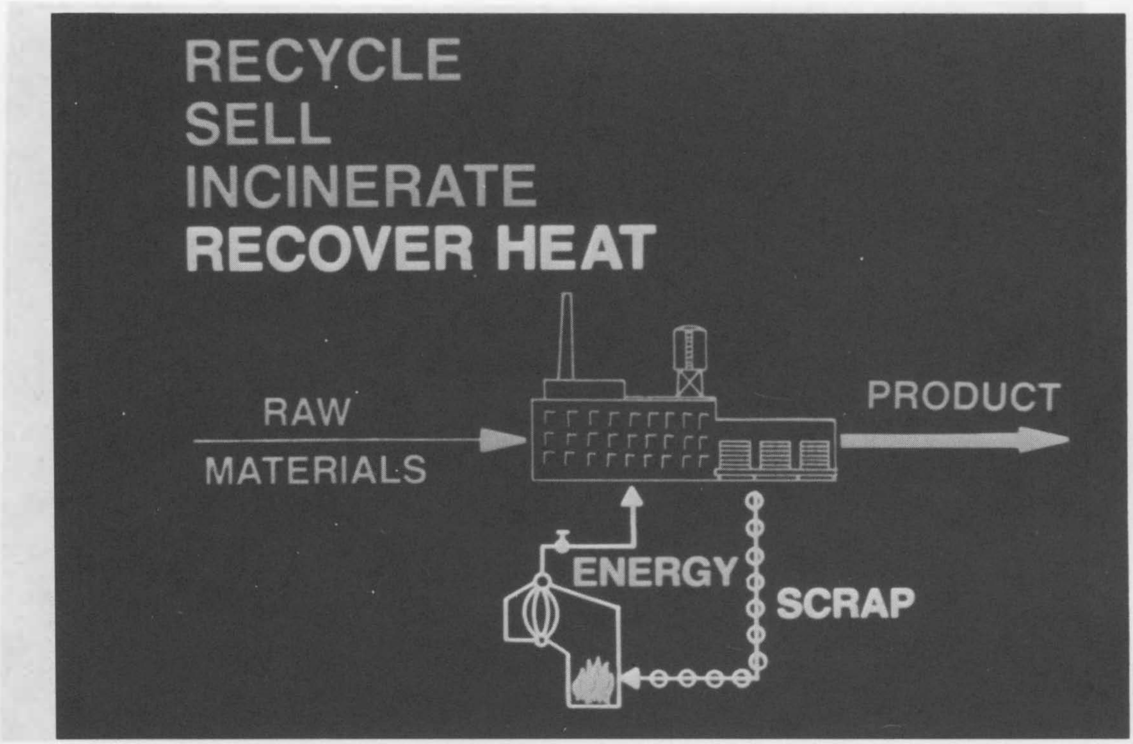
SLIDE 2



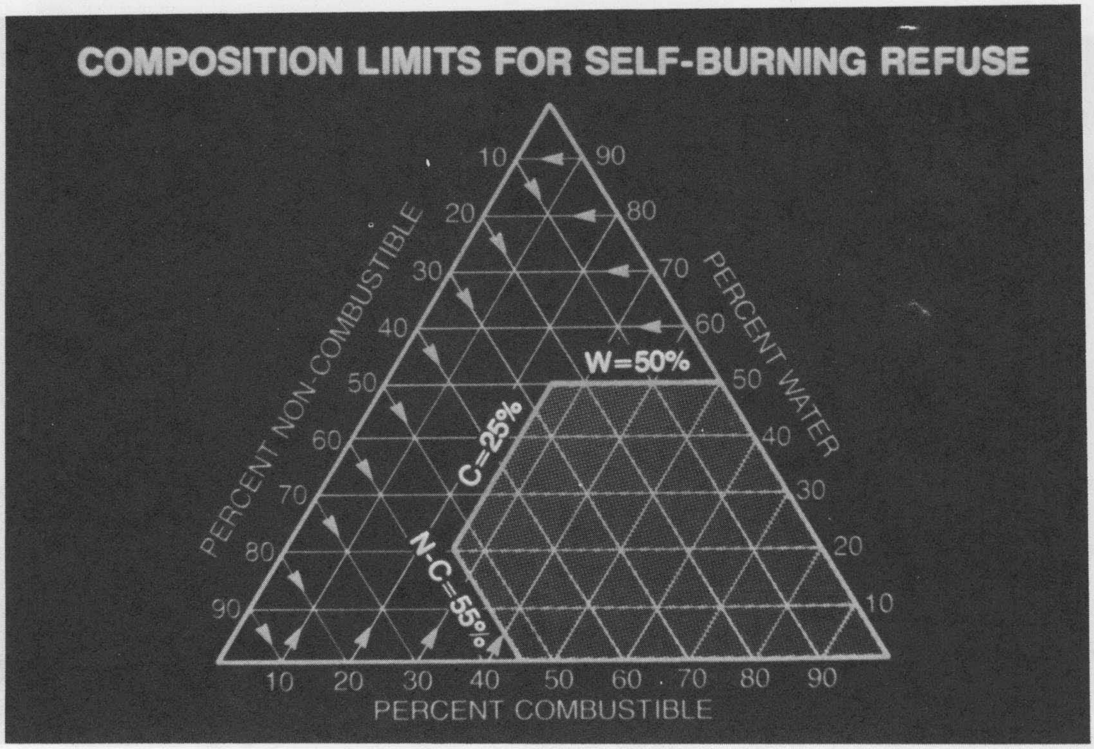
SLIDE 3



SLIDE 4


RECYCLE
SELL
INCINERATE
RECOVER HEAT
RAW
MATERIALS
PRODUCT
ENERGY
SCRAP

SLIDE 5


COMPOSITION LIMITS FOR SELF-BURNING REFUSE
PERCENT NON-COMBUSTIBLE
PERCENT WATER
PERCENT COMBUSTIBLE
W=50%
C=25%
N-C=55%
10
20
30
40
50
60
70
80
90

SLIDE 6

HEATING VALUE OF VARIOUS INDUSTRIAL WASTES

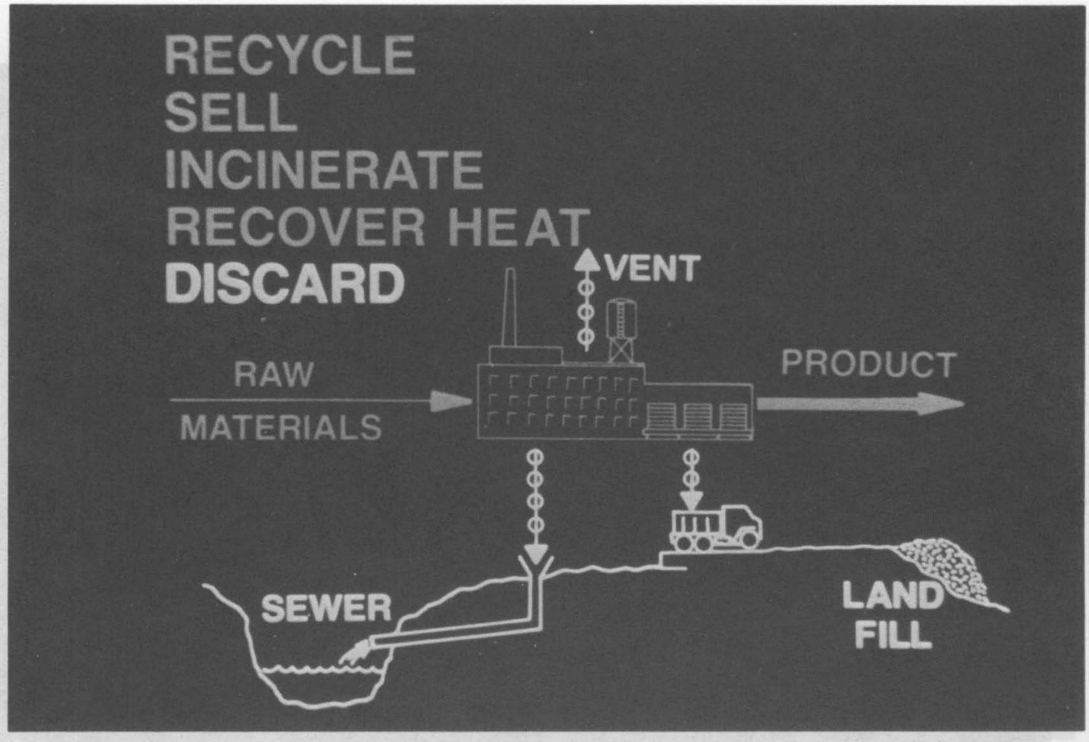
Waste Material	Heating Value BTU/#
Gases:	
Coke oven	19,700
Blast Furnace	1,139
Carbon Monoxide	575
Refinery	21,800
Liquids:	
Industrial sludges	2,000-12,000
Black Liquor	4,400
Sulfite Liquor	4,200
Dirty Solvents	10,000-16,000
Spent lubricants	10,000-14,000
Paints & resins	6,000-10,000
Oily waste and residue	18,000

SLIDE 7a

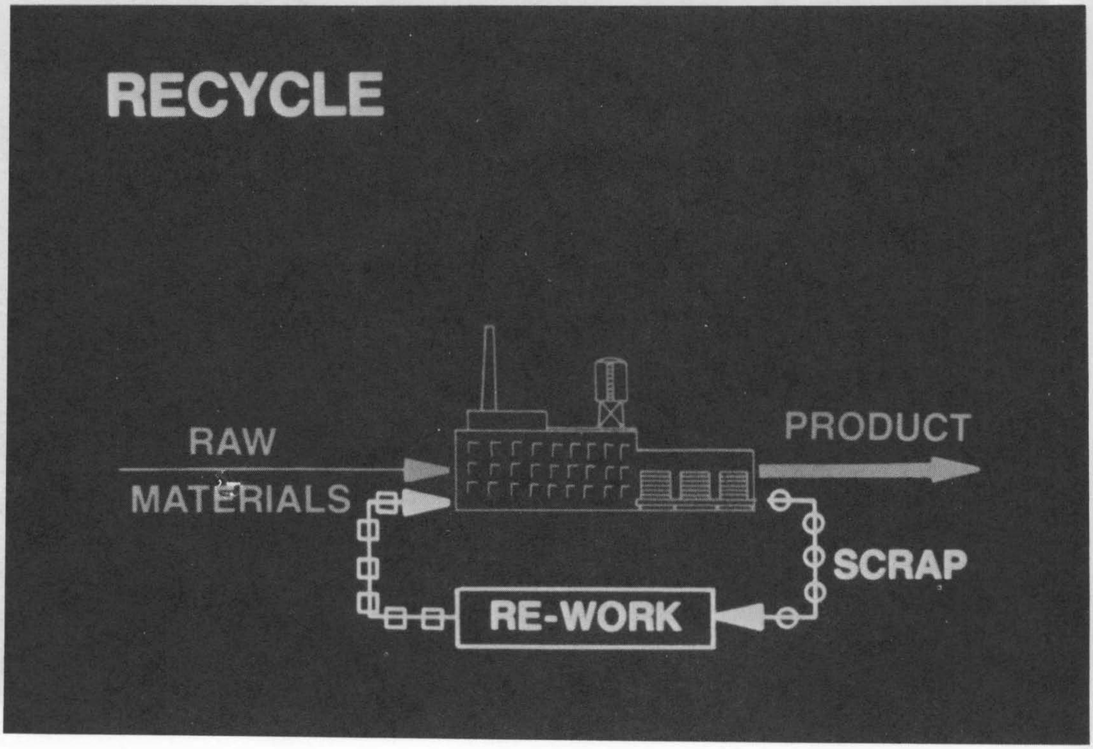
HEATING VALUE OF VARIOUS INDUSTRIAL WASTES

Waste Material	Heating Value BTU/#
Solids:	
Bagasse	3,600- 6,500
Bark	4,500- 5,200
General wood waste	4,500- 8,000
Sawdust & shavings	4,500- 7,500
Coffee grounds	4,900- 6,500
Nut hulls	7,000- 8,000
Rice hull	5,200- 6,500
Corn cobs	8,000- 8,300
Rubber wastes	11,500-19,700
Scrap tires	13,900
Leather scrap	12,000-19,700
Cork scrap	12,000-13,000
Paraffin	16,800
Polyethylene	19,700
Polystyrene	15,800
Polyurethane	11,200
Polyvinyl chloride	9,600-17,500

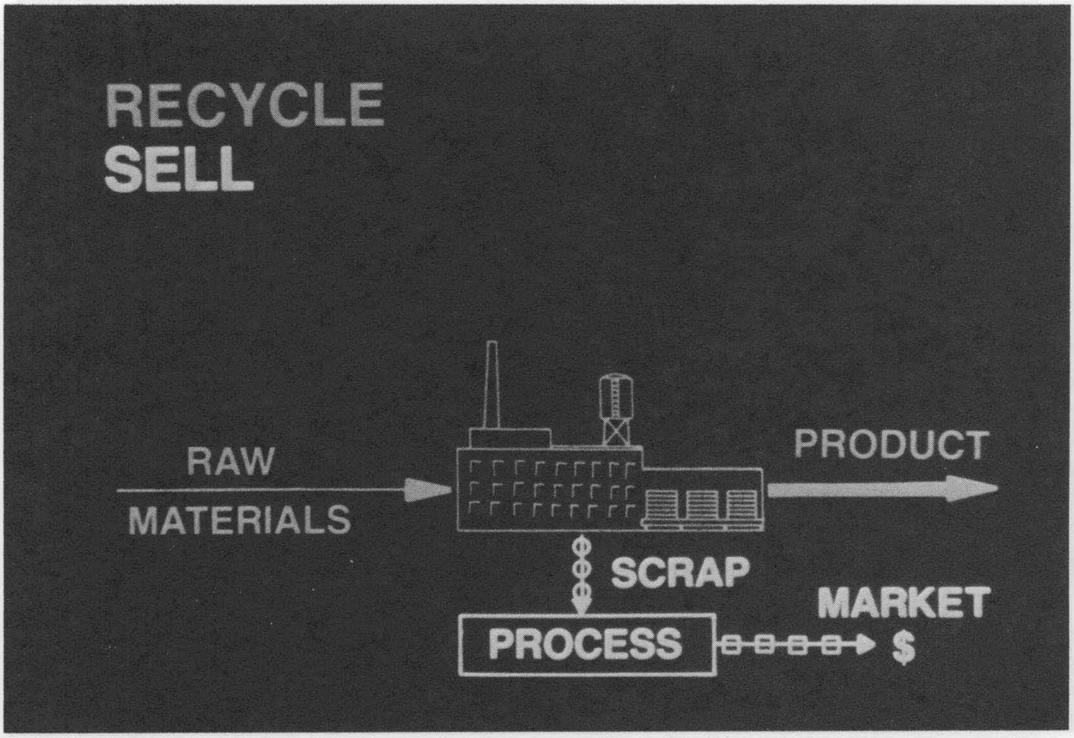
SLIDE 7b


RECYCLE
SELL
INCINERATE
RECOVER HEAT
DISCARD
VENT
RAW
MATERIALS
PRODUCT
SEWER
LAND
FILL

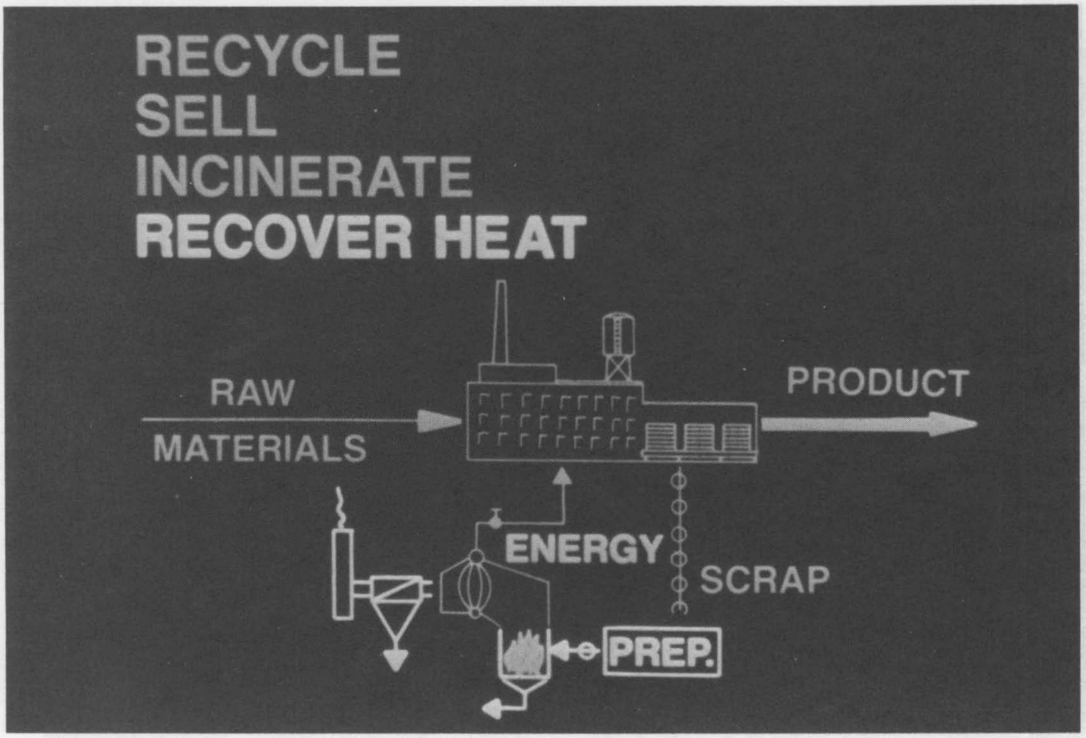
SLIDE 8



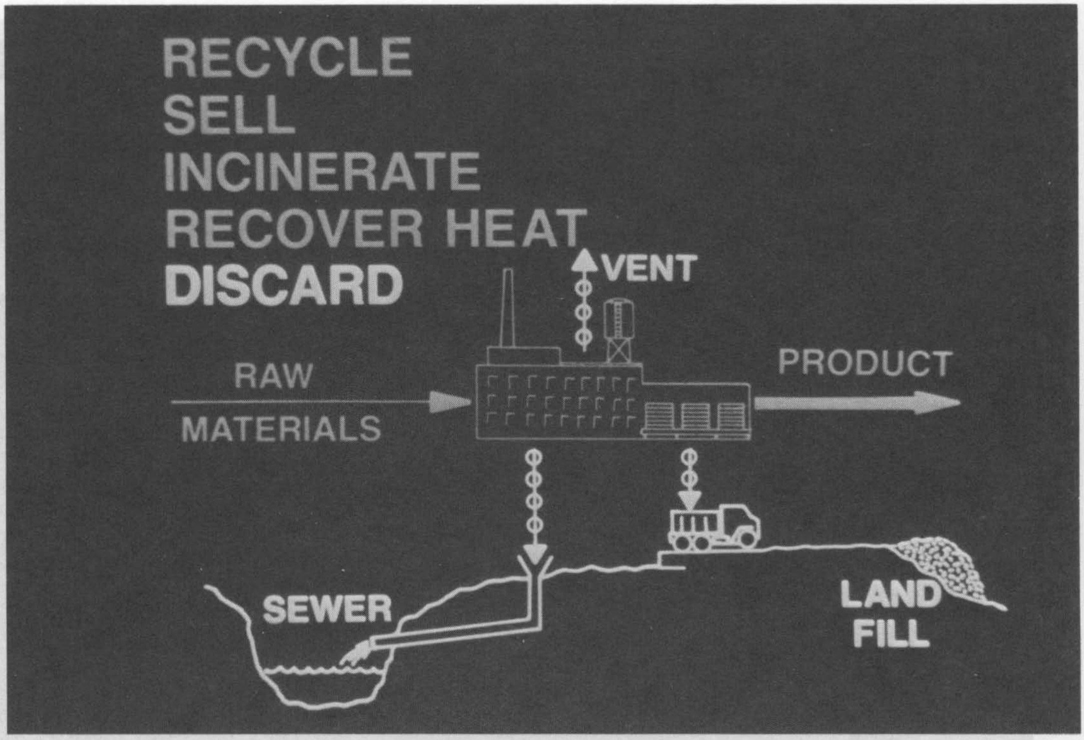
SLIDE 9



SLIDE 10


RECYCLE
SELL
INCINERATE
RECOVER HEAT
RAW
MATERIALS
PRODUCT
ENERGY
SCRAP
PREP.

SLIDE 11

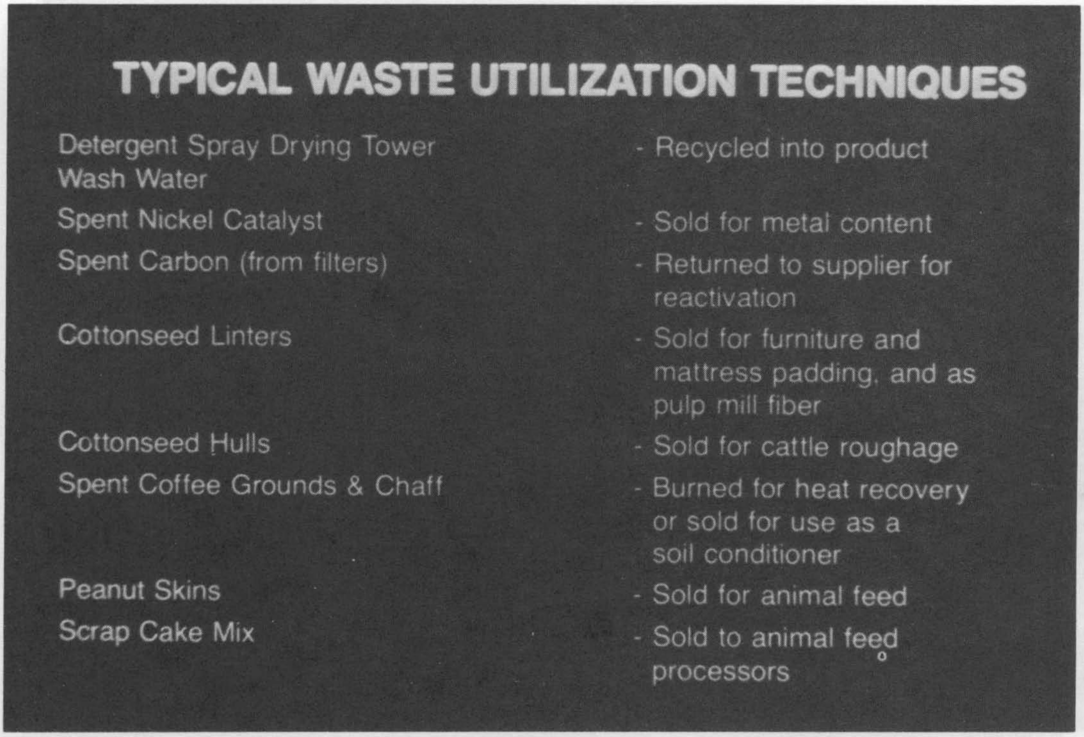

RECYCLE
SELL
INCINERATE
RECOVER HEAT
DISCARD
VENT
RAW
MATERIALS
PRODUCT
SEWER
LAND
FILL

SLIDE 12

TYPICAL WASTE UTILIZATION TECHNIQUES

Bark and Wood Waste	- Burned for heat recovery
Flyash from Wood Waste Burning	- Sold to activated carbon manufacturer
Spent Sulfite Pulping Liquor	- Burned for heat recovery
Kraft Black Liquor	- Burned for heat recovery and chemical recovery
Pulp Mill Rejects	- Sold for use in corrugated paperboard
Activated Sludge (Pulp Mill)	- Sold as plant food ingredient.
Turpentine	- Sold or burned for fuel value
Tall Oil	- Sold

SLIDE 13a


TYPICAL WASTE UTILIZATION TECHNIQUES
Detergent Spray Drying Tower Wash Water - Recycled into product
Spent Nickel Catalyst - Sold for metal content
Spent Carbon (from filters) - Returned to supplier for reactivation
Cottonseed Linters - Sold for furniture and mattress padding, and as pulp mill fiber
Cottonseed Hulls - Sold for cattle roughage
Spent Coffee Grounds & Chaff - Burned for heat recovery or sold for use as a soil conditioner
Peanut Skins - Sold for animal feed
Scrap Cake Mix - Sold to animal feed processors

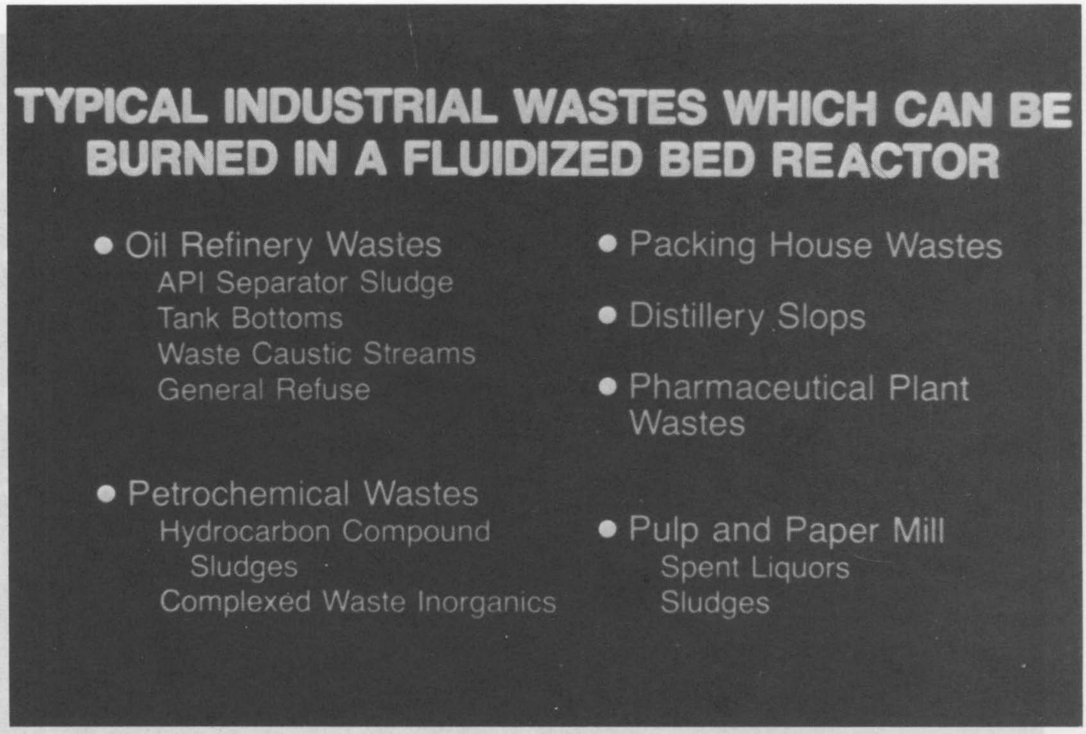
SLIDE 13b

SAMPLE LISTINGS:

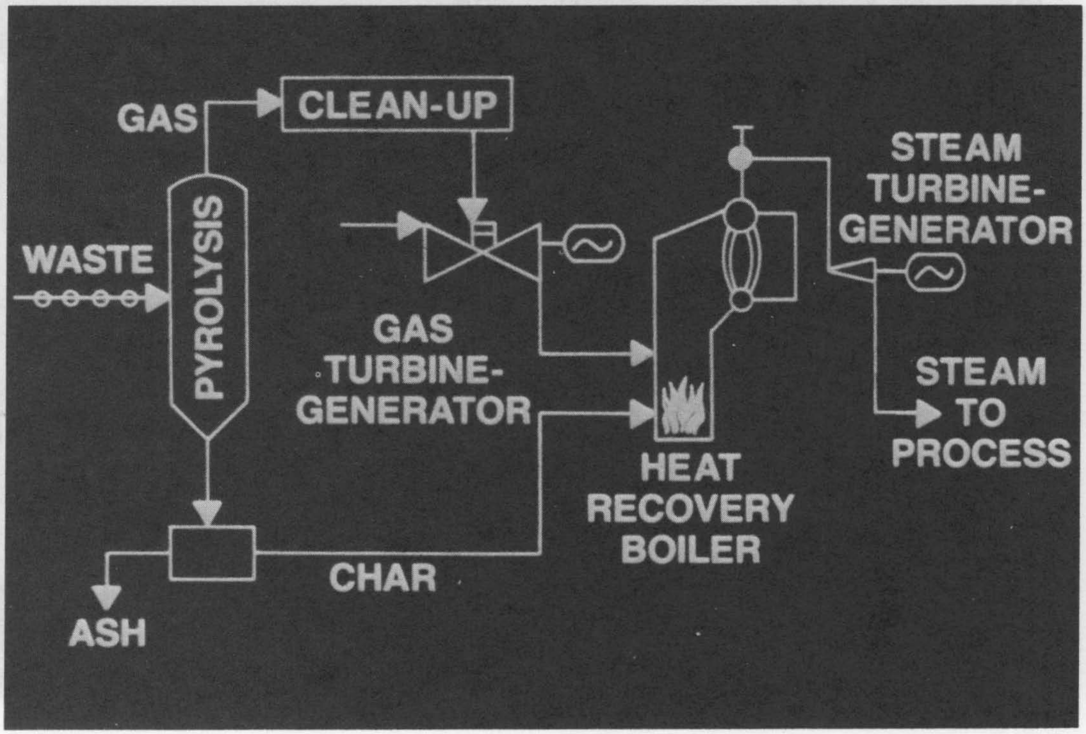
A 0001-75 Chrome (III) oxide, water content approx. 30%.
Dry weight composition: Cr_2O_3, over 99%, carbon, trace; kieselguhr, trace.
Quantity: Approx. 7 tons/mo.
Location: St. Louis

W 0001-75 Aluminum chloride, as hexahydrate or as solution with at least 10% Al, without heavy metals.
Quantity: up to 30,000 tons/yr
Location: St. Louis area, if possible

SLIDE 14


TYPICAL INDUSTRIAL WASTES WHICH CAN BE BURNED IN A FLUIDIZED BED REACTOR
• Oil Refinery Wastes
API Separator Sludge
Tank Bottoms
Waste Caustic Streams
General Refuse
• Petrochemical Wastes
Hydrocarbon Compound Sludges
Complexed Waste Inorganics
• Packing House Wastes
• Distillery Slops
• Pharmaceutical Plant Wastes
• Pulp and Paper Mill
Spent Liquors
Sludges

SLIDE 15


GAS
CLEAN-UP
WASTE
PYROLYSIS
GAS
TURBINE-
GENERATOR
STEAM
TURBINE-
GENERATOR
STEAM
TO
PROCESS
HEAT
RECOVERY
BOILER
CHAR
ASH

SLIDE 16