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

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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 con-
sidered 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, sewer ing, 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


RECYCLE

RAW MATERIALS → REWORK → SCRAP → PRODUCT
<table>
<thead>
<tr>
<th>Material</th>
<th>Energy (BTU/lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polystyrene</td>
<td>9,000 - 29,000</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>12,000 - 23,000</td>
</tr>
<tr>
<td>Steel</td>
<td>13,000 - 25,000</td>
</tr>
<tr>
<td>Aluminum</td>
<td>72,000 - 113,000</td>
</tr>
<tr>
<td>Copper</td>
<td>24,000 - 53,000</td>
</tr>
<tr>
<td>Zinc</td>
<td>24,000 - 40,000</td>
</tr>
<tr>
<td>Lead</td>
<td>20,000</td>
</tr>
<tr>
<td>Titanium</td>
<td>239,000</td>
</tr>
<tr>
<td>Glass</td>
<td>7,000 - 11,000</td>
</tr>
<tr>
<td>Cement</td>
<td>4,000</td>
</tr>
<tr>
<td>Paper</td>
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SLIDE 4
RECYCLE
SELL
INCINERATE
RECOVER HEAT

RAW MATERIALS

PRODUCT

ENERGY

SCRAP
COMPOSITION LIMITS FOR SELF-BURNING REFUSE
# Heating Value of Various Industrial Wastes

<table>
<thead>
<tr>
<th>Waste Material</th>
<th>Heating Value BTU/#</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gases:</strong></td>
<td></td>
</tr>
<tr>
<td>Coke oven</td>
<td>19,700</td>
</tr>
<tr>
<td>Blast Furnace</td>
<td>1,139</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>575</td>
</tr>
<tr>
<td>Refinery</td>
<td>21,800</td>
</tr>
<tr>
<td><strong>Liquids:</strong></td>
<td></td>
</tr>
<tr>
<td>Industrial sludges</td>
<td>2,000 - 12,000</td>
</tr>
<tr>
<td>Black Liquor</td>
<td>4,400</td>
</tr>
<tr>
<td>Sulfite Liquor</td>
<td>4,200</td>
</tr>
<tr>
<td>Dirty Solvents</td>
<td>10,000 - 16,000</td>
</tr>
<tr>
<td>Spent lubricants</td>
<td>10,000 - 14,000</td>
</tr>
<tr>
<td>Paints &amp; resins</td>
<td>6,000 - 10,000</td>
</tr>
<tr>
<td>Oily waste and residue</td>
<td>18,000</td>
</tr>
</tbody>
</table>
### HEATING VALUE OF VARIOUS INDUSTRIAL WASTES

<table>
<thead>
<tr>
<th>Waste Material</th>
<th>Heating Value BTU/#</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solids:</strong></td>
<td></td>
</tr>
<tr>
<td>Bagasse</td>
<td>3,600-6,500</td>
</tr>
<tr>
<td>Bark</td>
<td>4,500-5,200</td>
</tr>
<tr>
<td>General wood waste</td>
<td>4,500-8,000</td>
</tr>
<tr>
<td>Sawdust &amp; shavings</td>
<td>4,500-7,500</td>
</tr>
<tr>
<td>Coffee grounds</td>
<td>4,900-6,500</td>
</tr>
<tr>
<td>Nut hulls</td>
<td>7,000-8,000</td>
</tr>
<tr>
<td>Rice hull</td>
<td>5,200-6,500</td>
</tr>
<tr>
<td>Corn cobs</td>
<td>8,000-8,300</td>
</tr>
<tr>
<td>Rubber wastes</td>
<td>11,500-19,700</td>
</tr>
<tr>
<td>Scrap tires</td>
<td>13,900</td>
</tr>
<tr>
<td>Leather scrap</td>
<td>12,000-19,700</td>
</tr>
<tr>
<td>Cork scrap</td>
<td>12,000-13,000</td>
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<tr>
<td>Paraffin</td>
<td>16,800</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>19,700</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>15,800</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>11,200</td>
</tr>
<tr>
<td>Polyvinyl chloride</td>
<td>9,600-17,500</td>
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RECYCLE
SELL
INCINERATE
RECOVER HEAT
DISCARD
RECYCLE

RAW MATERIALS

PRODUCT

SCRAP

RE-WORK

SLIDE 9
RECYCLE
SELL

RAW MATERIALS

PRODUCT

SCRAP

PROCESS

MARKET

$
RECYCLE
SELL
INCINERATE
RECOVER HEAT
DISCARD

VENT

RAW
MATERIALS

PRODUCT

SEWER

LAND
FILL

SLIDE 12
<table>
<thead>
<tr>
<th>Waste Material</th>
<th>Utilization Techniques</th>
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<tbody>
<tr>
<td>Bark and Wood Waste</td>
<td>Burned for heat recovery</td>
</tr>
<tr>
<td>Flyash from Wood Waste Burning</td>
<td>Sold to activated carbon manufacturer</td>
</tr>
<tr>
<td>Spent Sulfite Pulping Liquor</td>
<td>Burned for heat recovery</td>
</tr>
<tr>
<td>Kraft Black Liquor</td>
<td>Burned for heat recovery and chemical recovery</td>
</tr>
<tr>
<td>Pulp Mill Rejects</td>
<td>Sold for use in corrugated paperboard</td>
</tr>
<tr>
<td>Activated Sludge (Pulp Mill)</td>
<td>Sold as plant food ingredient</td>
</tr>
<tr>
<td>Turpentine</td>
<td>Sold or burned for fuel value</td>
</tr>
<tr>
<td>Tall Oil</td>
<td>Sold</td>
</tr>
</tbody>
</table>
TYPICAL WASTE UTILIZATION TECHNIQUES

Detergent Spray Drying Tower
- Recycled into product
Wash Water
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
SAMPLE LISTINGS:

A 0001-75 Chrome (III) oxide, water content approx. 30%.  
Dry weight composition: Cr$_2$O$_3$, 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
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