Excess air

⑮ ⑭ × ⑩ = 3.47 × 0.30 = 1.04 t air/ton fuel

Total air

16 ⑭ + ⑮ = 3.47 + 1.04 = 4.51 t air/ton fuel

Fuel to stack gas

⑰ 1.0 − (⑥ + 0.05 × ②) = 1.0 − (0.18 + 0.01) = 0.81 ton gas/ton fuel

Total stack gas weight

⑱ ⑯ + ⑰ = 4.51 + 0.81 = 5.32 tons stack gas/ton fuel

Moisture in stack gases

⑲ ⑧ ÷ ⑱ = 0.592 ÷ 5.32 = 0.112 tons H_2O/ton stack gas

Specific heat of stack gas

⑳ 0.24 × (1.0 − ⑲) + 0.48 × ⑲ = 0.24 (1.0 − 0.112) + 0.48 × 0.112 = 0.267 Btu/lb.-°F

Stack loss per ton of refuse

㉑ ⑱ × ⑳ × (⑪ − 80 F) × ⑦ × 2000 lb/ton = 5.32 × 0.267 × (350-80) × 0.8 × 2000 = 620,000 Btu/ton of refuse

DISCUSSION

C. A. Johnson[2]

This paper provides the first consistent comparisons of the several energy resource recovery systems now being considered. Past comparative studies (e.g., a pair of papers at the CRE Conference in Montreaux, Switzerland in November 1975) used assumptions designed to reach the conclusion desired by the author. Unfortunately, the present paper is limited to thermodynamic considerations whereas economic results including the effects of capital costs and operating effectiveness are more likely to be decisive.

The author did not consider one type of system that is farther advanced than any except the raw refuse incineration; that is, the semi-suspension steam generation plant as in Hamilton, Ontario, or proposed for Albany, New York and Akron, Ohio. Hopefully, this could be added to the list in an addendum.

The conclusion to be drawn from the work is that if one desires to use the single proven energy recovery process, namely, incineration of refuse as received with byproduct steam production, the steam is best used for district heating and cooling or industrial processing as opposed to production of electricity. One could also reach this conclusion in two other ways. He could go to Europe and visit a few of the several hundred plants in operation there, or he could attempt to put together a project based on the sale of steam or prepared fuel to an electric utility in the United States.

R. C. Bailie[3]

The author in his approach recognizes the fact that the fuel products produced by either chemical, biological or mechanical treatment are only intermediate products that will ultimately be used in a combustion system to produce heat, steam or electricity. As the author has shown, the efficiency of the combustion system must be coupled with the fuel conversion system to provide a "Figure of Merit" useful in comparing alternative systems.

In order to compare alternatives it is essential to identify the "Objective" that is to be used as a basis of comparison. The author has provided two separate objectives—(*a*) steam and (*b*) electricity—and the various systems can be ranked according to each of these objectives. The ranking is shown in Table 6 attached to this review. It can be seen that the ranking of alternatives depends upon the objective chosen. The value of efficiency is often used as a measure for comparing alternatives. This leads to confusion and misunderstanding because efficiency is not a reasonable objective for comparison. This is because it is not a product stream of value and because it can be applied to parts of the process. For example it is possible to produce a low Btu fuel gas from waste at an efficiency of 70 percent but it will not sustain combustion and cannot be used as a source of heat or steam or electricity. (A worthless product with high efficiency.)

The author's approach will not lead to the confusion that has resulted from the use of efficiency and represents a major improvement in providing a "Figure of Merit" useful in ranking alternatives. The authors analysis leads to the ranking shown in Table 6 of this review and the ranking depends upon the objective considered. The results of the ranking are biased toward any large-scale system where higher conversions may be achieved (a large utility boiler has a higher energy conversion efficiency than a small industrial boiler). This bias is removed if the objective is changed from steam or electricity produced, to fossil fuel saved [11]. The ranking in terms of fossil fuel saved is shown in Table 6 in this review.

The author's contention that raw refuse incineration is as efficient as the alternative processes is re-enforced by the values provided in the attached table. If the alternative to raw refuse incineration are to be more energy efficient it will be as a result of (*a*) benefits not evaluated, or (*b*) error in the basic data in Table 3. The values in Table 3 are representative of those found in alternative references to those quoted in the article and appear reliable. Potential benefits not evaluated include energy costs associated with gas cleanup for environmental purposes (would favor Gas 2 alternative and detract from raw refuse incineration) and energy savings from recyclable materials (favoring mechanical processing and liquid product over other alternatives).

The author's combinations of the basic fuel processing step with the steam or electrical generating step allowed for the relative merits of alternative systems for the recovery of energy to be evaluated. The author's general conclusion that

Table 6 Ranking of alternatives

	Steam $^{(a)}$	Electricity $^{(a)}$	Fossil fuel saved $^{(b)}$ Steam	Electricity
Raw refuse incineration	1(1.00) $^{(c)}$	3(1.00)	1(1.00)	1(1.00)
Mechanical processing	2(0.89)	1(1.09)	2(0.83)	2(0.85)
Liquid	5(0.53)	5(0.65)	5(0.49)	5(0.49)
Gas 1	4(0.74)	4(0.68)	4(0.74)	4(0.69)
Gas 2	3(0.85)	2(1.06)	3(0.81)	3(0.82)
Biochemical processing	6(0.38)	6(0.46)	6(0.35)	6(0.35)

$^{(a)}$ Taken from Table 5 in paper
$^{(b)}$ Calculated for review
$^{(c)}$ Numbers in parentheses designate relative value (based on raw refuse incineration)

---

[2] Carrier Corporation, Syracuse, N. Y.

[3] Professor, Chemical Engineering, West Virginia University, Morgantown, W. Va.

the more recent processes developed for direct energy recovery from waste are no more efficient than an effectively operated raw refuse incinerator is valid. The values provided in tables are a valuable collection of reasonable energy requirements for various systems.

J. H. Fernandes[4]

Mr. Hecklinger is to be commended for sharing with us his study of the relative useful energy production between six selected refuse to energy systems. The methodology use in the comparison between systems was very meaningful. The data on the developing technology in pyrolysis and bioconversion I believe to be quite representative, but I am not in a position to seriously comment on these systems and will only address myself to the comparison between mass burning, or as the author refers to it, raw refuse incineration and prepared refuse or RDF, which he classifies as mechanical processing. I mention these other terms because they have been used frequently, and I have an objection to using the word —incineration—because of the unfortunate connotation the word conveys to the general public when one is referring to the thermal reduction of refuse.

I will restrict my discussions to the first two systems, because they are systems with which I am most familiar and my Company has a great deal of experience. C-E builds systems for industrial as well as municipal waste disposal. Referring to Table 3 where all of the essential information is presented, in the first two columns, one finds the comparison I will discuss. The assumed power requirements are about correct.

Neither system needs auxiliary fuels, so I see no problem here. In the mass burning system, the combustible loss in preparation is zero because there is no preparation. The refuse is mass burned. The 15-percent combustible loss charged against the prepared refuse due to air classification is high. This penalizes the system a little more than is necessary, I believe, it runs closer to half the stated amount. Most systems could not justify the loss of 15 percent of the combustibles in mechanical preparation. This is just too significant an amount to discard with the heavy fraction. I would appreciate comments from the separation specialist on this point. If it were only a single, coarse stage of classification with no further processing, it would still seem a little high. I just do not think that anyone would throw away this amount of the dry fuel value when there are simple methods to recover most of this heat to the furnance. A fairer value might be somewhere around 8 percent, and this would still be conservative because combustibles can be recovered during the downstream processing of the heavy fraction. There are many ways this recovered heavy combustible material can be handled. It could be reintroduced into the light fraction stream or it might be introduced on a small burn-out stoker at the bottom of the waste burning furnace.

Even if the power to drive the material's recovery equipment, which operates on the shredded refuse, were incorporated into the evaluation, it is not a substantial amount and would not affect the overall comparison of the two systems as much as the assumed 15 percent combustible loss.

An additional comment I have involves the combustible loss from the burning process. I know the equipment manufacturers use lower figures than the author. Our experience indicates that prepared waste fuels should burn with no more than a 3 percent carbon loss. C-E assumes a 2 percent carbon loss on a suspension fired boiler, while on a spreader stoker fired unit, which would require some preparation of the refuse, the carbon loss is nearer to 3 percent. We consider a carbon loss of up to 3½ percent for a mass burning unit, but we would accept the author's 3-percent estimate. The doubling of the loss when it is a prepared fuel being fired is the problem. Not knowing the details of the system considered or having access to the author's data, it is difficult to judge, but if this is representative of his system, he should probably look for a better system—they are available. I would appreciate the author's comments. This is a difficult loss to measure accurately and varies. So if the author had charged them equally at 5 percent, it might have been acceptable, but I question a doubling of one with respect to the other.

The author is to be commended for bringing to the reader's attention the fact that the economics, the capacity of the plant and byproduct benefits of a particular system can be extremely important and can be the deciding factors rather than just the energy requirement. One must remember that this paper addresses itself only to the energy requirements of the various systems. I am in agreement with the rest of the first two columns in Table 3. They are substantially as we see these particular figures.

We actually consider the steam generation values a bit differently, but it works out about the same. We consider a mass burning unit to be capable of approximately 60-65 percent overall steam generator efficiency, whereas the suspension fired unit burning prepared refuse will run 70-75 percent efficient. This, as the author points out, is essentially due to the difference in air quantities used and the exit gas temperature allowed. However, as important as this is, there are other factors that must be considered. One, of course, is corrosion. If heavy metals are not released in the furnace, they will not contribute to the corrosion problem, to say nothing of the potential health hazard when these metals are disbursed in the atmosphere. Another important criteria that should be considered when talking in terms of energy production, is the consistency of production and the stability of the steam conditions. Other authors[5] have pointed out the problems with variation in steam pressure and flow due to the uneven burning conditions in a mass burning system. Most steam generating units servicing electric generators would require some sort of accumulator or similar flow stabilizing system in the circuit when mass burning. This conforms to the author's reasoning that when prepared refuse is suspension fired, combustion takes place in a very short interval of time and therefore the heat release in the furnace can be accurately controlled, because "preparation" homogenizes the fuel.

In closing, except for the couple of points I would like clarified, the analysis is very professional and definitely a worthwhile contribution to the literature.

D. B. Sussman[6]

I would like to commend the author on his excellent approach in comparing the relative value of energy available from solid waste in different systems. With energy recovery from solid waste becoming a viable alternative to other methods of solid waste disposal, the need for a comparison of the energy recovery potentials of the various technologies becomes imperative. Mr. Hecklinger's paper does much to take the guesswork out of the comparison.

There are a few points that I would like to comment on. The data that Mr. Hecklinger used came from systems promoters and much of it was based on prototypes and engineering estimates. Although the lack of hard data would not modify Mr. Hecklinger's relative values by a significant factor, I am concerned that someone who has little understanding of the

---

[4] Combustion Engineering Inc., Windsor, Conn.

[5] Foster Wheeler, "The Quality Control Approach REFUSE The World's Wasted Energy Source," *Heat Engineering,* June-Aug. 1975.

[6] Environmental Protection Specialist, Office of Solid Waste Management Programs, U.S. EPA, Washington, D. C.

tables will quote these absolute numbers as the Gospel. I believe that a cautionary note should be incorporated into the paper.

The ASTM Resource Recovery Committee (E-38) is considering a standard procedure for determining the energy value of solid waste. I believe their approach and other approaches that we in EPA are working on would consider the energy yield of an amount of solid waste a percentage format, rather than comparing various systems and technologies to baseline system. In any case, Mr. Hecklinger's paper would be invaluable to the E-38 committee, and I suggest that a copy be made available to them.

Mr. Hecklinger's conclusions are fine but the importance of item four may get lost. I have drawn a slightly different set of conclusions. They are:

1 As solid waste is converted into a fuel or energy source, it loses a portion of its intrinsic energy in the process. The more complex the conversion, the less energy is available for export.

2 The range of conversion efficiencies is not great. A factor of 1.09 using the mechanical processing method of electricity on the high end to 0.46 at the low end for biochemical processing to electricity. This swing is in the two-to-one range and is, in my opinion, not a significant difference.

3 In view of the foregoing, other factors could have a greater impact on technology selection than energy conversion efficiencies.

4 Therefore, markets for the energy products, system economics, and other site specific parameters must be considered in making the determination as to which technology will be best.

One last item, the Btu content of the fuel gas produced by thermochemical processing—Gas 1 is listed at 30 Btu/ft^3 @ 1200 F. It should be 130 Btu/ft^3 @ 1400 F or 4.9MJ/m^3 @ 760 C.

E. M. Wilson[7]

Through development of a consistent set of data and application of a reasonable methodology, Mr. Hecklinger has made a valuable contribution to a field where too often false conclusions have been drawn. The field, however, tends to be *one where no relatively short discussion will permit a reader to* obtain a totally objective "answer" to his needs for establishing an energy recovery facility at a given site. Single facets in the evaluation criteria cannot be isolated and intercomparisons then made for a candidate series of processes. The word "value" in the title must include all positive and negative factors of product worth to the user and the affected community. Facility capital and operating costs must be in*cluded in these factors. The conclusion that raw refuse in*cineration has a lesser combustible loss than supplementary fuel suspension-fired systems because of a 3600 times greater residence time for the former must be viewed from the point of the costs associated with achieving the slightly higher energy yields. These costs can be expressed as economic ones or in terms of the energy that was associated with all elements of facility construction (metal production, transportation, fabrication, etc.), *but an accounting of their effect on value* must be established.

Current activities of the ASTM in reviewing energy accounting schemes for waste-derived fuels and eventually establishing standards are to be commended. The first two issues of the new journal "Resource Recovery and Conservation" examine the problems of such accounting for various products from both a thermodynamic and mathematical basis. The range of possible results, which are more or less all equally "valid," and the consequent ability to skew any ranked listing should give caution to anyone attempting to determine the optimum energy recovery process. Mr. Hecklinger's approach should be considered as a preliminary net energy review procedure that might be applied prior to a later more detailed study. In the final engineering decision making analysis, such factors must be quantified as annualized capital and operating costs, environmental control, product revenue magnitude and market stability, and possible changes in waste suply and characteristics for a given geographical source of refuse. Only then will some idea of the relative value of energy derived from municipal waste be established.

J. B. Presti[8]

I have just completed a review of the paper presented, and as a result I have the following comments:

1 The paper does not include an analysis of a mechanical processing system in which the prepared refuse fuel (RDF) is burned, by itself, on a spreader stoker type grate. This process is very different from either the "Raw Refuse Incineration" system or the "Mechanical Processing" system which are included in the paper.

Using the same bases as used in Tables 4 and 5 of the paper, an RDF/spreader stoker process would give a relative value—as compared to 1.0 for raw refuse incineration—of 1.07.

2 In comparing the Net Electrical Energy obtained from refuse, a turbine heat rate of 9750 Btu/kWh was used for the lower pressure (680 psi) steam, and 8000 Btu/kWh was used for the higher pressure (1800 psi) steam. These turbine heat rate values are for a 16.5-MW turbogenerator and a 150-MW turbogenerator, respectively. However, if the processes are to be compared for the same project, then the generator size for each case should be the same, and the turbine heat rates would be as follows:

Generator size	680-psi steam	1800-psi steam
165 MW	9750 Btu/kWh	9160 Btu/kWh
150.0 MW	8960 Btu/kWh	8000 Btu/kWh

With these foregoing turbine heat rates, the relative values, as shown in Table 5 of the paper, will change as follows:

System	As presented in paper	**16.5-MW** generator	**150.0-MW** generator
Raw refuse incineration	1.00	1.00	1.00
Mechanical processing	1.09	0.95	1.00
Liquid fuel	0.65	0.57	0.60
Gas 1 fuel [(a)]	0.68	0.68	0.68
Gas 2 fuel	1.06	0.93	0.97
Biochemical processing	0.46	0.40	0.42
Mechanical[(a)] processing (spreader stoker; see comment 1)	1.07[(b)]	1.07	1.07

(a) These processes all generate the lower pressure (680 psi) steam; therefore, their relative values remain the same

(b) See comment 1

3 The data used for Thermochemical Processing Gas 2 (the PUROX System) is based on a reference brochure published *before* any test results from their South Charleston facility.

On the other hand, the data used for the incineration processes and other Thermochemical processes are based on references using actual operating data. This distinction is of

---

[7] The Ralph M. Parsons Company, Pasadena, Calif.

[8] Titan Environmental Services, Paramus, N. J.

paramount importance to anyone interpreting the results and conclusions of Mr. Hecklinger's paper.

F. Hasselriis[9]

Mr. Hecklinger presents an energy accounting procedure for comparing a spectrum of refuse-derived-fuel-to-energy systems ranging from minimum preparation mass-burning incinerators with boilers to systems producing more refined fuels which can be burned elsewhere. In his informal remarks he regretted not having included in his tabulation dry, powdered fuel such as Ecofuel ^{TM} II, due to lack of sufficient published information.

These comments are an effort to evaluate this highly refined solid fuel using the methodology of Mr. Hecklinger, and to compare the energy effectiveness of the Ecofuel ^{TM} II process, including conversion by combustion to heat and power, with the other processes he tabulated.

Fuel Characteristics. By size reduction, drying, cleaning and milling, a dry powder fuel is produced, similar in size to pulverized coal (PC), having an ash content of about 8 percent, a density of 30 to 35 lb per cu ft, and a heating value of 8000 to 8500 Btu/lb (18 to 20 GJ per metric ton of fuel). It can be burned with pulverized coal burners in suitable furnaces subject to the same limitations as PC relating to slagging, fouling, ash and particulate control.

Power Requirements. Grinding to a fine powder by the Ecofuel^{TM} II process does not take substantially more power than coarse shredding for many reasons, including the greater ease of grinding dry materials. For purposes of comparison with simple mechanical processing cited as 30 kWh per ton, we can take 60 kWh per ton as conservative. Most of this power contributes to drying the material and thus is not lost.

Combustion. A dry, powdered refuse-derived-fuel provides consistent, easily controllable combustion with the low excess air requirements of liquid fuels. Five percent excess air has been demonstrated to be sufficient in a burner requiring 30 percent excess for PC with normal moisture even when air dried in the feeder. Normal boiler conditions are more likely to require 10–15 percent excess for dry solid fuel or liquid fuel, however. Dry solid fuel has been demonstrated to improve the combustion of residual oil when the two fuels are burned together.

Mositure in solid fuels substantially delays combustion, requiring a longer flame, a larger furnace, and more excess air to compensate for the combustion delay, as well as producing substantial amounts of unburned combustible in the flyash and bottom ash.

Energy Required for Drying. Relying on furnace heat for drying places a severe burden on furnace combustion, derating the boiler by adding excess air and moisture to the gas flow, and limits the amount of RDF which can be burned in the boiler. Dry powdered Ecofuel^{TM} II can be burned as 100 percent of boiler fuel, subject to the same limitations as PC, and sometimes to limitations in existing PC feeding and handling equipment. The preparation process removes most of the dirt, leaving mainly inherent ash, similar to that of PC.

The combustibles left behind by the cleaning process can be burned separately, thus providing the heat needed for drying the product fuel. The heat balance comes out about even: thus the heat recovery efficiency is equivalent to mass burning of raw refuse as distinguished from simple mechanical processing which rejects a substantial portion of combustible in the process of air classifications and also retains product moisture and large particle size, both deterrents to combustion.

Energy to Steam and Power. By using the entire combustible fraction and then being able to burn the fuel in a power boiler with minimum excess air, substantial gains can be achieved in conversion of refuse energy to steam or power.

The following tabulation is condensed from Hecklinger's Tables 3, 4 and 5, and is based on Ecofuel^{TM} II, 15 percent excess air, no combustible loss, vaporization loss the same as Raw Refuse, and the miscellaneous loss and power boiler conditions the same as Mechanical Processing.

	Ecofuel^{TM} II	Raw refuse	Mechanical processing
Total power requirement	90 kWh	30 kWh	60kWh
Combustible loss in process	–	–	**15%**
Combustible lost in combustion	–	3%	**7%**
Energy in fuel	10.50 GJ	10.50 GJ	8.95 GJ
Combustible loss	–	−0.31	−0.64
Vaporization loss	−1.40	−1.40	−1.15
Heat available	8.12 GJ	6.63 GJ	**6.23 GJ**
Less steam equivalent of electrical energy	−0.84	−0.28	−0.21
Net refuse energy to steam	7.28 GJ	6.35 GJ	5.67 GJ
Relative value	1.14	1.00	0.89

In conclusion, it is illuminating to evalute various processes in their entirety from MSW to steam or power to discern the factors which generate the end result. We must also, of course, be aware that other factors can dominate the total picture, such as site considerations; tipping and landfill charges; transportation costs; plant costs; refuse, steam and power load factors, and market value.

Author's Closures

Reply to Dr. Johnson. Unfortunate or not, I deliberately limited my paper to a thermodynamic analysis using data published by the system developer or sponsor with the conclusion that it is difficult to better the thermodynamic efficiency of the basic incineration process. If this was understood by those evaluating the various systems under consideration today then we would not be confronted with the statement found in reference [8] on p. 12 where an inflated efficiency figure on 51 percent (one can calcuate 44.5 percent from Tables 3 and 4) is cited as ". . . relatively good compared to other utility plants (fossil fuel, steam or electric, nuclear, waterwall incinerator, etc.)."

I would have included the Hamilton, Ontario plant if I had had sufficient and appropriate published data.

Reply to Prof. Bailie. There is a bias towards any large-scale operation. However, it is not necessary or important to remove this bias as certain systems are inherently more suitable for large scale operations than other systems.

Energy costs associated with gas cleanup are included in Table 3 as part of power requirement under the heading of "Combustion." The allowance may not be adequate for some systems, however. For example, the gas scrubber that is a part of thermochemical processing—Gas 1 has proved to be incapable of meeting Federal standards. Raw refuse incineration, on the other hand, has been shown to be in compliance in a number of installations.

Reply to Dr. Fernandes. I, too, was surprised to learn the magnitude of lost combustibles in processing and the unburned combustible loss in combustion of prepared refuse cofired in suspension in utility boilers. As noted in the paper, all data used for the mechanical processing system was interpolated from test data gathered for the St. Louis demonstration plant. It is "interpolated" since the data ac-

---

[9] Combustion Equipment Associates, Inc., N. Y.

tually used is somewhat *better* than that reported. (Note that another conference paper by Fiscus, Gorman and Kilgroe concludes that unburned combustible loss at St. Louis is 10 percent whereas I used a figure that amounted to 7.2 percent [12].)

The quantity of combustible material lost in the processing phase varies from process to process depending on the degree the processor strives to minimize noncombutible and abrasive material in the fuel. At Ames, Iowa, a smaller percent of combustible material is lost in the processing phase than at St. Louis. However, it has been reported that "the early efforts to determine the net heat value of the solid waste fuel delivered to the electric utility boilers indicated that 87 percent of the heating value of the fuel is actually burned in the boilers." [13] In other words, unburned combustible loss at Ames appears to be 13 percent in the tangentially fired boiler. The Ames experience with spreader stoker fired boilers seems to be considerably better in this regard. On the other hand, I understand that in an effort to produce a fuel of higher quality, the processes being developed by Americology and the National Center for Resource Recovery anticipate a fuel that is roughly 60 percent by weight of the incoming refuse. In their process, I estimate that at least 25 percent of the raw refuse heating value will be lost in processing.

My experience with traveling grate, raw refuse burning stokers manufactured by Combustion Engineering, Inc., is that they tend to have a higher unburned combustible loss than the reciprocating grate and rocking grate stokers used in the referenced raw refuse systems.

The comments regarding corrosion and health effects of heavy metals are, to the best of my knowledge, speculative. There is room for research work in this area.

Reply to Mr. Sussman. While it is correct that much of the data came from "systems promoters" based on "prototypes and engineering estimates" it is significant that from an energy standpoint most of the data from the promoters of untested systems compares *unfavorably* with data from systems that have been proven in operation.

I suppose that one can never include sufficient cautionary notes to preclude misuse of data. The same comment may be applicable to EPA publications.

I have been active on the ASTM Committee E-38 on Resource Recovery since its inception.

The heating value of the fuel gas produced by thermochemical processing—Gas 1 is in Btu's per *actual cubic foot*. This can be calculated from the volumetric analysis for Gas 1 or it can be extrapolated from reference [8, pp. 9 and 10]; where we learn that "gas temperature is controlled to 1200 F" and has "about 120 British Thermal Units (Btu) per *dry standard cubic foot.*" I calculated that the actual gas contains 12.8 percent H_2O by weight and 18.5 percent H_2O by volume assuming that it is produced by evaporation of moisture in refuse and combustion of auxiliary fuel. Thus:

$$120 \text{ Btu/dscf} \times (1.000 - 0.185) \times \frac{(460+70)}{(460+1200)}$$

$$= 30 \text{ Btu per wet cu ft at } 1200 \text{ F.}$$

Reply to Mr. Wilson. As mentioned in the reply to Dr. Johnson, this paper was limited to thermodynamic considerations. In retrospect it seems that "thermodynamics" or some similar word might well have been used in the title.

In my opinion, a study to determine the energy associated with facility construction (metal production, transportation, fabrication, etc.) would be basically an academic exercise and of little practical value.

Economic evaluations, particularly when resource recovery is involved, are highly site specific. Therefore, attempts to develop nonsite specific or general evaluations tend to be very misleading. This problem is compounded when one is forced to compare actual construction costs for one system against the system developer's projected costs for an untried system.

Reply to Mr. Presti. Without supportive data, there is no way to evaluate Mr. Presti's claim of high efficiency for spreader stoker firing compared to raw refuse firing. The only operating unit of this type is in Hamilton, Ontario, for which I do not have published data. I do know, however, that the operators of that plant have found it necessary to use auxiliary fuel continuously in order to maintain combustion. I would guess that Mr. Presti did not use auxiliary fuel in his determination.

Some systems are inherently adaptable for use with larger, more efficient turbine generators. Thus, raw refuse incineration was penalized with a low heat rate turbine generator.

The only data used in the paper that came from actual full-scale operation was for raw refuse incineration and mechanical processing.

Reply to Mr. Hasselriis. Like Mr. Presti, Mr. Hasselriis has prepared an evaluation to demonstrate the thermodynamic superiority of his process. While his data is apparently not from published sources, it is in sufficient detail to permit specific comments.

Ecofuel II is a dry powder "similar in size to pulverized coal." Pulverized coal is normally considered to be ground to a fineness so that 70 percent will pass a 200 mesh USS sieve which has a nominal aperature of 0.0029 in. The Thermochemical Processing – Liquid system includes processing to an average fineness of 0.015 in. (5 times larger than pulverized coal) by means of two stages of shredding with an intermediate stage of drying to 3 percent moisture [7]. The power requirements for size reduction in the thermochemical processing – liquid system are expected to exceed 110 kWh per ton of raw refuse based on "Prolonged testing over many months. . ." [7]. Meanwhile, we are told that "we can take 60 kWh per ton as conservative" for Ecofuel II. Supportive data is required.

As I understand it, the drying stage for Ecofuel II is dependent on "combustibles left behind by the cleaning process" with a heating value precisely equal to the heat of vaporization of moisture in the processing fuel. The reject combustibles are burned separately without auxiliary fuel and with zero losses. The heat thus released is then used in an 100-percent efficient dryer to evaporate moisture in the processing fuel. Obviously, this cannot be.

Additional References

11 Bailie, R. C., and Doner, D. M., "Evaluation of Energy Substitution Equivalent," *Res. Rec. and Cons. I,* 1975, pp. 188-191.

12 Fiscus, D. E., Gorman, P. G., and Kilgroe, J. D., "Bottom Ash Generation in a Coal-Fired Power Plant When Refuse-Derived Supplementary Fuel is Used," *Proceedings of the 1976 National Waste Processing Conference,* ASME, New York, N.Y., 1976.

13 Sedore, J. K., "Use of Community Refuse for Boiler Fuel," American Power Conference, Chicago, Ill., 1976.