UTILIZATION OF WASTE PRODUCTS FOR THE SUPPLY OF ENERGY TO INDUSTRIAL UNITS

REPORT OF THE SUB-COMMITTEE

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Introduction.

A perfect industry cannot have any waste product either as forms of energy, or matter. Therefore, waste product is a good symbol of improperly handling a processing system.

In Sri Lanka, and everywhere in the world except desert and very cold areas, agrowastes are the most abandant type of waste; next come the waste products from various industries.

Even now some developing countries consider agrowastes as a burden; whereas in developed areas almost all the agrowastes are used beneficially. With the fuel scarcity, especially in poor countries which do not have fossil resources found, agrowastes are already becoming national treasures rather than wastes.

Mountains of coirdust which are getting accumulated in certain coconut growing areas, slowly burning heaps of rice husks in paddy growing areas, ugly looking urban and municipal wastes used as landfills, huge heaps of saw dust in timber milling areas, water hyacinth, salvinia and all the others nuisance weeds ----- in short any biomass --- should already be treated as energy treasures rather than wastes in Sri Lanka.

Internationally, thousandsof publications appear monthly on biomass waste utilization for energy and raw material derivation.

The scope of this report is to show very briefly the feasibility of using locally available waste products for energy derivation.

Derivation of valuable raw materials, and chemicals is left out of the discussion. But this too is an equally important item under the prevailing raw material and energy hungry conditions.

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PADDY HUSKS -- AN UNTAPPED NATIONAL TREASURE[1]

Sri Lanka being a paddy producing country, paddy husks or paddy hulls are found abundantly here, and hitherto have not been utilized adequately. This inevitable product of rice milling, has been an expensive nuisance to millers of rice in large quantities not only in Sri Lanka, but also in many developed and developing countries. Being very bulky and slow burning, and thus being ignored, this agricultural waste is today establishing high hopes in many developing countries; especially, in those where natural fossil fuel resources are not found up to the present time. Many rice millers in Sri Lanka, who once used imported fuels to transport paddy husks from their mills for dumping on empty patches of land or water, are today utilizing the "nuisance waste" derived heat energy to turn many a wheel in their factories and to parboil rice etc.

Countries like Nepal and Thailand, it is understood, are using almost all of their paddy husks to produce energy for rice milling, while in Japan most of the paddy husk is used for industrial purposes, and very little for producing energy. Just burning for extraction of heat energy is not the optimum solution, because it leaves around one-fifth of its weight in silica, which consequently is a bigger or smaller nuisance creating disposal problems. Our recent investigations are showing that paddy husks are being used in an unprecedented scale as a substitute for firewood in many urban, and even suburban, areas in Sri Lanka. The price of paddy husks, used as a domestic fuel in home-made small cylindrical ovens or burners, has already gone up to Rs. 2.50 per gunny bag-ful . The most important fact is that most millers are not in a position to satisfy this domestic demand even for a few months. Being used for small industrial uses, like in the preparation of tooth-powders, cleansing media and fillers in adhesives etc., paddy husk ash, completely burnt to greyish white, fetches for certain millers more than Rs. 5.00 per gunny bag-full.

Firewood, becoming rarer and more expensive, is a threatening problem to a paddy husk-fuelled industry in small milling areas in Sri Lanka. In small milling reas, already husks are available only for very short periods. A decisive factor is that, a paddy husk industry should get paddy husks almost free of charge or at some very small cost which depend on so many other parameters.

Variable Parameters

Burning rice husk to get heat is a simple process. But to efficiently recover heat from burning, to burn at such a rate that it will be worth to extract heat for processess, and to reduce environmental pollution that may be caused by burning require carefully controlled conditions, and equipment. However, a compromise has to be arrived at, when the technical and economical conditions in a developing country like Sri Lanka is considered.

A lighted stick or any hot flame will not flame up a heap of paddy husks immediately. Because of its high silica-cellulose arrangement, imparting a relatively high fibrous strength and abrasive character, rice husks differ from many other types of common agricultural wastes. The characteristic, 'drinking straw bundle' structural configuration, as is popularly known, is a clear indication of its high resistance to burning under normal condition, in which firewood, saw dust, coir dust, straw, leaves and many other agricultural solid materials will burn. Further, silica, being a good absorber of moisture and the main constituent in sand, should definitely contribute to the slowness of rice husks catching fire. Rice husks are found in over 75 countries through-out the world. By weight of harvested paddy, husks constitute 14 to 35% by weight.

The heat energy obtainable by completely burning a heap of rice husks vary widely. Type of rice, country of cultivation, climate and seasons of harvest, soil, humidity, and mode of fertilization may affect the constituents in paddy, which in turn will affect the ash content. Some Italian vatieties have yielded an ash content as low as 14 by weight of husks, while some American varieties had been analyzed to show a value as high as 27%. On an average, however, 20% of husks by weight of milled rice is considered as an average. Therefore, derivation from paddy husk should have to take into consideration this very important but highly variable parameter. A rescrutiny of a chemical analysis of paddy husks in Sri Lanka, as mentioned in a United Nations' Food and Agricultural Organization Publication, has shown that the manner in which the results have been obtained were erroneous, and thus the results were not reproducible.

Haphazard collection of the samples of husks and the application of non-standard methods in the analyses, non-availability of appropriate literature, and often negligence, are the very probable causes of such chaos. Various results of analyses, in a span of hundred years from 1871, of 32 varieties of paddy husks, for their physico-chemical properties has been published by D. F. Houston (1972, U.S.A.).

An extraction is quoted in Table 1.

TABLE 1

Composition of Paddy Husks**

Component	Water	Crude Protein	Crude Fibre	Ash	Cellulose
Range ...	2.4 to 11.35	1.7 to 7.26	31.7 to 49.92	13.16 to 29.04	34.3 to 43.8

**All the components are not included. All the values are given as percentage by weight of paddy husks.

It is clearly evident from Table 1, that constituents of paddy husks vary from variety to variety in a big range. This mode of variarion, however, should not make the entrepreneur uneasy in a paddy husks energy industry, because what matters mainly is the heat content of a particular variety husks and its ash content.

Transport and Storage

Paddy husks from milling, in which the familiar concave-convex profile still remains, has a density of nearly 17 to 25 pounds per cubic foot (272 to 400 Kg per c.m.) . The true density (compacted) of paddy husks is nearly 45 pounds per cubic foot (720 Kg. per cubic meter): that is nearly 3/4 that of water. This is the average density of many types of timber, and only by mechanical compression of paddy husks can this value be reached. However, the very high silica content in paddy husks causing high wear and tear of hardware is disadvantageous. A gunny bagful of paddy husks will weigh nearly 20 to 25 Kg only. This bulky nature of paddy husks has been a nuisance not only for the rice miller but also to the environment and to society.

The size of huge heaps of paddy husks gets reduced not only by burning, but also by being blown by wind over rice milling areas. Waste heat, poisonous gases and fumes generated during the slow process of natural burning, and fly ash and husks pollute our environment. Leaving aside all that, pile burning of rice husks is unsatisfactory and an aesthetic eyesore. That is why burning of rice husks in open public places is prohibited. Paddy husks are strongly resistant to natural decay. When damp or rain soaked, and decomposing, piles of paddy husk may get self-ignited through the heat generated by the natural decay. This indicates that storage of paddy husks in a dry condition is imperative if it is going to be used only with the course of time. On the other hand, dry storage of paddy husks requires large spaces and massive structures, which becomes prohibitively expensive in urban areas. When stored in large heaps, paddy husk can be ignited very easily and if allowed to burn can result in big fires due to gasification.

A Fuel in Cement Industry

NERD Centre has successfully established a very useful process to utilize the heat content of rice husk in the prodrction of a masonry cement . Rice husk is the only fuel, advantageously leaving the silica ash as another raw material , used in the manufacture of this cement .

A village level model burner for this cement in which one ton of Rice Husk Fuelled Cement can be produced , is now almost completed at the NERD Centre.

It is now planned to set up a semi-industrial cement producing unit in a rice growing area in Sri Lanka .

The raw materials used in the production of this masonry cement are rice husks , limestone and clay .

PRODUCER GAS FROM RICE HUSKS[2]

When rice husk is burned in the presence of only a limited supply of air, it gives rise to a mixture of gases, known collectively as producer gas, consisting principally of carbon monoxide and hydrogen, which are inflammable, and the non-inflammable gases carbon dioxide and nitrogen. If water vapour is introduced into the generator the proportion of hydrogen in the mixture is increased.

The use of this gas mixture in internal-combustion engines has been practiced for many years, but has been confined chiefly to the stationary engine, in which the weight and size of the necessary generator and cleaners are unimportant. Its successful utilization as a fuel for motor-powered vehicles presents difficulties, but from time to time efforts have been made to adapt it to them. During world War 11, producer-gas-fueled vehicles were extensively used in many countries.

Countries most interested, for both economic and political reasons, in the utilization of producer gas as a source of power are those dependent on foreign supplies of oil.

Producer gas can be utilized for drying purposes, for steam generation, for partial substitution of SNG in internal-combustion engines, for the generation of electricity or for other commercial heating usage. It can also be used to replace or supplement liquid fuels if the burner or engine is equipped with the proper mixing and control mechanisms.

During World War 11, rice-husk-derived producer gas was used to supplement the town gas system in Vercelli, Italy. The mixture used (59% fossil gas of 4350 cal and 40.5% rice-husk gas of 1500 cal) resulted in a net 3200 cal gas, yielding an overall saving of 23% of the coke requirements of the town's system.

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Also, a few rice mills utilized rice-husk gas derived from fueled producer-gas units for fuel for paddy trucks, bottled at about 200 atm.

In Italy during and immediately after World War 11 there were 57 rice-husk-powered rice mills. Only one remained with the installation intact in 1975. It has recently been reported that a rice mill at Kouroma, Mali, is powered with a Chinese producer gas/ic engine system.

From 100 kg of husk, Possenti[2] Produced 100-130 m^3 gas, 2-4 kg tat, 20-25 kg carbon, 1.22-1.24 kg/m^3 density of gas with a heating value of 1300 - 1600 $kcal/m^3$.

1 hp/hr required 1.8-2.4 kg of husk, assuming 20-22% efficiency.

It is possible to produce a generator gas of 2500 $kcal/m^3$, as compared with the 8000 $kcal/m^3$ of natural gas.

A comparison of gas composition and comparative caloric values of wood blocks, sawdust and rice husks is shown in Table 02.

TABLE 2

Gas composition and caloric values of rice husk and other fuels

FUEL DATA	For Reference Wood Blocks	Sawdust	Rice Husk
Net. Cal. Value per 1b (dry)	7,750 B.Th.U.	6,350 B.Th.U.	6,340 B.Th.U.
Fixed Carbon	18.7 %	20.67 %	17.4 %
Moisture	0.0	0.0	0.0
Volatiles	77.0	78.4	60.9
Ash	4.3	0.93	21.7
Lbs./B.H.P.(Dry)	1.75	2.2	2.2
Lbs./B.H.P. (29% Moisture)	2.2	2.8	2.8
CO_2	6.9 %	12.2 %	3.0 %
O_2	0.2	0.8	0.4
CO	28.1	18.2	32.2
H_2	13.9	10.2	6.4
CH_4	3.7	3.2	0.6
N_2	47.2	55.4	57.1
Cal. Value per cu. ft. gross at 60° and 30"	170 B.Th.U.	123 B.Th.U.	135 B.Th.U.
Cu. Ft./Lb. of Fuel (Dry)	32	33	30
Cu. Ft./Lb. of Fuel (20% Moisture)	25	26	24

A primary advantage of gas-producer systems is that minimum attendance is required. The system is relatively simple in design and thus maintenance is nil. One of the most critical design requirements is the removal of ash from the producer. It is important to note that depending on the ultimate usage, the producer gas may or may not require a filtring and scrubbing system to remove entrained particulates.

In summary, rice husks can be economically gasified to produce a combustible gas with a calorific value of approximately 130 to 150 BTU/ft^3. This producer gas can be utilized to drive a gas engine or trubine-generator or to provide steam to drive a rice mill or electric generator in the range of 5 to 220 HP or even higher. Coupled with generating units, these gas engines would prove a valuable source of power for general industrial and lighting purposes, and particularly for developing the rice industry. They can provide an ample and cheap power supply for irrigation pumps, farming equipment, milling plants and by-products processing installations[2].

Coir Dust: The "Lethargic" Fuel.

Sri Lanka has about 450,000 hectares of Coconut lands and the annual production is about 2,000 million nuts. The fibre industry uses about one thirds of the Coconut husks available and produces about 100,000 tons of coir fibre yearly.

The husk of a Coconut weighs about 350 g. on air dry basis and yields about 140 g. of fibre. The balance 210 g. consisting of, pericarp pith and short fibre i is termed coir dust. The annual output of coir dust is estimated to be about 150,000 tons on air dry basis.

Coir dust has had no significant commercial or domestic use till now. The islandwide air dust output over the 30 years period 1951-1980 is estimated to be 4,000,000 tons. A fair portion of this is still available in heaps near fibre mills.

PROPERTIES OF COIR DUST

Physically coir dust consists of 85-90% of pith and 10-15% short fibre by weight. The chemical, proximate and ultimate analysis are,

Cherical Analysis(1) (Dry basis)		Proximate Analysis(2) (Dry basis)		Ultimate Analysis(2) (Dry, Ash free basis)	
Cellulose	30%	Fixed Carbon	26%	Carbon	46%
Hemi Cellulose	12%	Volatiles	62%	Hydrogen	7%
Lignin	47%	Ash	12%	Oxygen	46%
Ash	11%			Nitrogen	1%

The higher heat value on dry ash free basis is about 21,000 KJ/KG.

Coir dust as it discharges from the fibre mill has a moisture content of about 85%. The conventional drying of the material needs more fuel than what is produced by drying it. Mechanical dewtering systems and solardrying systems have to be used.

Air dry coir dust at 10-15% moisture content has a density of only 80 kg/m^3. Therefore its use as a fuel is feasible only within a very short distance from the centre of production.

This article is excerpted from reference No: 4 of the list given at the end of this report.

A commercial briquetting machine was adopted by Ceylon Tobaco Company Limited after modifications to produce briquettes with a density of about 1,200 kg/m^3. These briquettes are about 75 m.m. in diameter, adjustable in length and could be stacked to have a bulk density of about 800 kg/m^3.

A pilot coir dust processing plant has been constructed adjacent to a fibre mill in Negombo, and has been commissioned early this year. This plant is designed to produce 4,000 kg. of briquettes in 8 hour working day.

COMPARSION WITH OTHER FUELS

The cost of useful heat delivered by the combustion of coir dust briquettes is compared below with traditional fuels. The combustion efficiency is based on an exhaust gas temperature of 200° C.

Cost	Firewood	Coir Dust Briquettes	Furnace Oil	Heavy Diesel
Delivered Cost (Rs/kg.)	-/40	1.50	4.60	6.60
Ash (%)	2.0	5.0	0.2	0.02
Moisture (%)	35.0	10.0	1.0	-
Heat Value (kJ/kg)	11,700	19.200	42,500	44,000
Combustion Efficiency	72	79	81	81
Useful heat kJ/kg	8,400	15,200	34,460	35,000
Cost of useful heat Rs/GJ	47.60	98.70	133.70	185.40

The cost of coir dust briquettes is assumed to be Rs.1.50/kg. in the above comparison. This includes the cost of transport upto 150 km, financial cost of capital investment and taxes. The use of briquettes close to production centre, tax incentives and soft financing could reduce the cost appreciably, making coir dust briquettes a very attractive alternative to fuel oils for heating purposes.

The first attempt to use coir dust briquettes was with tobaco curing. These trials were conducted at Hanwella Research Station of Ceylon Tobacco Company Ltd. The trials consisted of curing two identical barn loads of tobacco one using firewood and the other with coir dust briquettes. These cures confirmed that coir dust briquettes could be used effectively as a fuel in flat grate furnaces designed for firewood and coal.

This plant has been working on coir dust briquettes for over three months. During this period it has recovered about 50% of the cost of conversion of the furnace. The cost of production of Cinnamon Oil has been reduced by about 10%.

The only adverse condition observed during all these three sets of trials was slag formation over fire bars at high burning rates. The improvement in pilot plant machinery reduced slag formation progressively.

The technology for processing waste coir dust into fuel briquettes and for its use in industrial furnaces has been developed. The economics are very attractive as a replacement for fuel oils, but not favourable against firewood at current prices.

Ceylon Tobacco Company has decided to operate its boiler at Essential Oils Plant continuously on coir dust briquettes. A boiler at its Tobacco Factory will be converted for briquettes in in the next two months. The Company foresees the operation of most of its boilers using briquettes and factory waste in near future.

The Ceylon Tobacco Company Limited is satisfied with the trials carried out so far and now intends to establish about 20 coir dust processing plants in collaboration with Coconut Development Authority by end of 1983. This is the first stage of a project which in full development will utilize about 200,000 tons of waste coir dust annually. The completion of the Project will result in saving of about 80,000 tons of industrial fuel oil which is about a third of the annual national requirement, and equivalent to Rs.400 million at present prices. The additional benefits to the millers and further advantages by introduction of gasification and power generation stages will not only make it even more attractive financially but will also assist the rural electrification schemes and energy conservation programmes of the Government.

MUNICIPAL AND URBAN WASTES

Municipal waste can be divided into two categories :-

1. Human waste
2. Non human waste.

Around Colombo one can see a few places like Peliyagoda, Grandpass and Nawala getting dumped with municipal waste in a big scale.

True that it is being done as a way to fill the land, and also to dispose the waste , but it has chronic ill effects. Bad smell, flies and pests pollute the environment; moreever it is an aesthetic eyesore.

Municipal wastes is a real burden in all the socieites. But developed societies handle them exemplary in a very useful way. High technology is required to get profit from handling this type of waste.

Municipal waste is mainly composed of paper, food and vegetable wastes , plastics cloth, glass , aluminium, iron etc. in various forms .

Municipal or urban waste can be processed as follows -

a. Preparation as a solid fuel.
b. Pyrolysis to a fuel gas.
c. Pyrolysis to fuel oil.
d. Anaerobic digestion to a fuel gas.
e. Combustion / Turbogenerators.
f. Incineration with heat recovery .

The first and the last ways are the most used processes in developed countries. Of the processes available , incineration to produce steam is the simpliest method . The most costly process appears to be the anaerotic digestion of municipal waste because of its high operating cost.

Interest continues at a high level concerning the disposal of organic solid wastes and where possible, recovering energy or materials that can be recycled from those wastes. New installations are coming on stream and are being monitored carefully. As a result , information is being published in the journals of professional societies , publications dedicated to solid waste management , books , and reports by government agencies . Some of these sources are reviewed here in an overview of problems and approaches .

The Volume and Composition of Waste

The physical volume of waste is enormous . Its impact on the ecology is of great concern. The amount of solid waste generated per person per day in this country varies very widely .

Although the total appears large , estimates of the usefulness of this waste must take into account the source of waste , its distance from the markets for energy or recyclable materials , and its heating value. Volumes and compositions of waste are site-specific . Wide variations occut from one season of the year to the next. The level of industrial activity in a specific area also influences waste composition and volume. Although much literature exists concerning the production of feed , gas , or products of fermentation from waste, disposal practices are only beginning to change. Most waste goes to landfill , while some is incinerated. Resource recovery is increasing as landfill space becomes less available and the economics of waste disposal change.

As the consumption of energy neared peak levels in the 1970s add a reasonable estimate could be made of remaining fossil fuel resaves , the need for increased recycling became obvious. Since most municipal waste in the United States is cellulosic in nature, it represents a source of energy whether it is combusted or converted into liquor or gaseous fuels . It is likewise realised that recovery of the metals and the glass for recycling represents a significant savings of energy . Aluminium is one example . Primary aluminium ingots require 244 million Btu/ton. Recycled aluminium requires only about 32 million Btu per ton , achieveing a saving of 62,000 kwh/hr per ton of aluminium.[5]

Estimates of the resource values in municipal waste vary considerably . An idea of the range , abstracted from several publications can be seen in Table 4 . Composition varies with location and many other factors. Moisture content of the asreceived waste averages between 25 and 35%.The as-received materials has a heating value between 4000 and 5000 Btu/lb. Methods of analysis are described in a recent publication In general, the methods used for the analysis of coal are applied to the wastes.

The European Comparison.

The composition of the waste in several European cities was recently reported by Dr. Alter. Many of the results are in the range reported in Table 4 A few notable exceptions are evident . The percent of discarded paper in most cities is below that of the U.S. Only Stockholm and Vienna fall in the same range as the U.S.

TABLE 4 - Range and Composition of Municipal Solid Wastes.

Combustible	Weight Percent
Paper	35 - 60
Garden wastes	2 - 35
Food	2 - 8
Cloth	1 - 3
Plastics	1 - 2
Noncombustibles	
Metal	6 - 9
Glass	5 -13
Dirt	1 - 5
Moisture	20 - 40

From a practical standpoint , the potential use of waste disposal sytems that recover energy is limited to three choices;(1) a water wall incinerator; (2) cocombustion of waste with a fossil fuel; or (3) pyrolysis to a combustible oil or gas. The first two have been demonstrated on a commercial scale. The other one has been demonstrated in process development units conesuming about 200 tons/day , about the size of a commercial module in some cases.

All processes considered have certain features in common. Some seperation can take place at an early stage such as the removal of clean cloth and bundled paper. These two items periodically have a good market value ; if not , they are sent to the shredder, and air classifier. The underflow from the classifier goesthrough magnetic seperation , dense media seperation , linear motor seperator , an electrostatic seperator and / or color sorters for the glass. Concentrated organic waste then goes to combustors or reactors. After products are recovered , the residue is made acceptable for landfill. These processes are capital intensive, closely coupled unit operations. The obvious risk is great when the plant scale is large.

The Decision Making Process

Handling municipal wastes is as much a social problem as an economic one.

Local governments could be hard pressed to make decisions about the selection of the proper waste disposal and / or energy recovery system for their area. Problems could occur because of the advanced technology involved plus the related problems of finance and system management. The capital costs of recycling are high . The choice of a disposal system might have to be made from unproven alternatives. Warnings continue concerning the need to do something about the wastes discharged to the environment. The admonitions concern the deepest oceans and caverns of the earth to be stratosphere. Concern is for the impacts on resources, places to dispose of waste materials and the potential destruction of the environment. Perhaps we can no longer wait. The time may be here to make a selection from today's best systems.

The chemist or chemical engineer can provide significant support as a member of a task force or as a consultant.His specialized knowledge can help as the design evolves . These inputs can provide city engineers and officials with insight into the system under consideration. The result can be formulation of more precise questions for the vendors , and thus the purchase of a better recycling system. Insight into the technologies also helps officials feel comfortable that they can make the best decision regarding system selection. A challenge to municipalities is to make an intelligent choice from numerous alternatives , finding the best one for their situation.

This lower cost has reduced the urgency of complying with the plan that the city filed with the state environmental department. The long range plan calls for the conversion of solid waste to energy. Two other factors, however, come into the local planning ; the continuing availability of landfill sites and the social value of creating new energy supplies.

Gassification: A Well Matching Process For us.

It is obvious that access to reliable and comparatively cheap power sources is of great importance for increasing the productivity in developing countries. Until now, internal combustion engines using gasoline,or diesel oil fuel have been used extensively for this purpose.

The use of such engines forms the entire basis for the transportation sector, is of paramount importance for development of a more effective agriculture, and appears as the most attractive alternative for generation of electricity on a small scale.

Provision of petroleum fuels for all these internal combustion engines is, however, growing into a more and more difficult economic problem. As a consèquence, there has been an increasing interest for a alternative, renewable sources of energy, like solar energy, wind and biomass.

Considerable efforts are made to develop suitable technologies for utilization of such energy sources. It appears, however, that there exists only one option if one wishes to find a substitute for the gasoline or diesel engine which can be introduced today without much further research and development, namely utilization of the producer gas technology which was applied during the second world war in many countries that were suffering from the disturbances of the supply of petroleum fuels.

The main advantages with the producer gas option in comparison with other conceivable alternatives, are the following:

- The technology has once been used on a large scale. There exists a fund of experience, which can be utilized when the technology is re-introduced.
- The technology appears to fit well into the present infrastructure, since there exists already an organization to handle service and maintenance of the most complicated component of the system, i.e. the internal combustion engine.
- The equipment required to convert to the present vehicles and small power plants to the new energy source is fairly simple to manufacture. Manufacturing can probably be done in most developing countries.
- The energy efficiency of the system is comparatively high, and the cost of installation comparatively low.[6]

CURRENT ACTIVITIES TO RE-INTRODUCE PRODUCER GAS

There appears to be an increasing interest in developing countries to re-introduce producer gas for utilization of biomass fuels to operate internal combustionengines. The applications considered range from small irrigation pumps with a power requirement of a few kw, to car and truck engines village power plants , sawmills, irrigation pumps and fishing vessels with engine powers of 15-150 Kw, up to power plants with a power of several hundred Kw. In most countries the number of plants in operation is small and limited to a few experimental units or demonstration plants.

It appears that the two countries which are leading the re-introduction of producer gas are Brazil and the Philippinnes. In Brazil there appears to be five or six companies that manufacture and sell gasifiers suitable for small and medium sized engines . Some 700 units are in operation , mainly with charcoal as a fuel.

In the Philippines the introduction of gasifiers appears to have strong official support . Based on research and development since 1967 and extensive field testing of gasifier units for irrigation pumps and vehicles , a government company " Gasifier and Equipment Manufacturing Company (GEMCOR)" was established.

A prototype down-draft gasifier was designed and constructed by the Department of Chemical Engineering of the NERDC during 1980-1981 . Various fuels like wood , charcoal, coconut husks , coconut charcoal were tested. Due to the urgency in solutions for the energy problem in Sri Lanka , the project on Gasification was diverted into two directions; Namely Stationery Bed - Down Draft Gasification and Fluidized Bed Gasification .

With the devoted work of Dr.A.N.S.Kulasinghe,NERDC successfully demonstrated a vehicle, waterpumps, and generators running on individual gasifiers during the First International Conference on Producer Gas held in Colombo during November last year.

A Fluidized Bed Gasifier is test running at the NERDC. The aim of this type of Gasifier is to use particle fuels like saw dust, rice husk, coir dust , etc. Fluidized Gasifiershave the advantage that they can use these fuels without the tedious and expensive process of briquetting. Hopeful results are obtained with the fluidizing gasifier : indicating that many agro-residues can be successfully used to replace imported oil.

VARIOUS BIOMASSES

The energy potential in biomass can be released by direct combustion or by converting these materials into fuels or chemicals either thermochemically or biochemically. The following sections discuss technologies for combustion and conversion. Although greater detail is given for processes that have advanced beyond the laboratory experimental stage, an attempt has been made to include sufficient data to provide a broad overview of the various processes, products, and potential wastes.

Combustion.

Combustion of biomass is usually described as proceeding through four consecutive steps: (1) evaporation of moisture, (2) distillation of volatiles, (3) burning of volatiles, and (4) combustion of fixed carbon. Step 1 is endothermic, step 2 can be either endothermic or exothermic, and steps 3 and 4 are definitely exothermic, providing the desired heat. The vaporization of moisture absorbs about 2675 kJ/kg (1150 Btu/lb) (2442 kJ/kg (1050 Btu/lb) of moisture evaporated plus 233 kJ/kg (100 Btu/lb) to break the hydroscopic bond between water and wood.

Not only is vaporization of moisture the most important heat-absorbing portion of the combustion process, it is the source of increased particulate emissions (Arola 1977), requiring so much heat that biomass containing more that 60% moisture will barely support combustion. Step2, the distillation step, is also somewhat endothermic, below about 260° C (500°F), although it probably absorbs more than about 465 kJ/kg (200 Btu/lb) of distilled volatile matter (Kreisinger 1939). The bulk of the distillation process, however, takes place between 282 and 482°C (540 and 900°F) and is exothermic in this temperature range (Shelton 1978). In the presence of air at a temperature of about 593°C (1100°F), the evolved volatiles ignite and burst into flame, producing large quantities of heat. Among others, the most abundant compounds volatilized are carbon monoxide, carbon dioxide, methane, wood alcohol or methanol, formaldehyde, hydrogen, and formic and acetic acids. In the absence of sufficient air or at temperatures below the ignition point, these gases are emitted uncombusted and constitute a major source of wood-burning chemical pollutants. This is almost in variably the case when wood is burned in open air or in residential fireplace . In fact few wood stoves are designed to provide the additional forced air and temperature necessary to ignite and burn the evolved gases.

Moisture in wood

Commercial boilers, on the other hand, are designed to extract all the possible heat from fuel and thus generally provide more complete combustion.

Table 5 Effect of moisture content on the heating value of wood and wood products.

Moisture (%)	Heat value per lb (Btu)	Heat required to evaporate water[a] (Btu)	Net heat remaining (Btu)	Water/ dry wood (lb/lb)
0	9000	0	9000	0.00
10	8100	120	7890	0.11
20	7200	240	6960	0.25
30	6300	360	5940	0.43
40	5400	480	4920	0.67
50	4500	600	3900	1.00
60	3600	720	2880	1.50
70	2700	840	1860	2.30
80	1800	960	840	4.00
90	900	1080	-180	9.00
100	0	1200	-1200	

The effect of moisture content on the heating value of wood is given in Table 5 Clearly, the heat required to evaporate the moisture in wood takes a severe toll on the originally available heat. At 50% moisture, which is common for wood as received or undried, wood of 20,900 kJ/kg (9000 Btu/lb), only 9000 kJ/kg (3900 Btu/lb) remain to provide heat and maintain a suitable combustion temperature. Lowering the temperature of the fuel bed has several important environmental consequences. A low temperature is conducive to high particulate emissions and to incomplete combustion, with its consequent emission of unburned hydrocarbons and combustible gases such as carbon monoxide.[7]

Bagasse.

Combustion of bagasse and some other agricultural wastes for the generation of energy is practiced widely . Although the unit heating valye may not be as high as equivalent weights of natural gas or petroleum , there is a negligible raw material cost, only that necessary to move it from the mill to the boiler. The field collection of wastes and transportation to a cental point for combustion is usually energy deficient , that is, the energy consumed is geeater than the energy in the load. When agricultural wastes are used for steam raising , it is necessary for the combustion zone to be designed for the particular fuel being fired. Account must be taken for the heat release the moisture content , of the feed , its particle size , the need for supplemental fuel, and ash removal. Other factors may also be significant in pasticular cases.

Bagasse is an appropriate example. Normally it contains 40 to 55% moisture after it is pressed add ready for disposal. Its moisture-free chemical composition averages 43% carbon , 6% hydrogen , 47% oxygen and 2% ash. The moisture ash-free higher heating value is about 8500 Btu/lb. Since steam generation is considered, the heating value of bagasse is only about one-half that of an equivalent weight of coal after correcting for the moisture and ash. The composition of bagasse is about the same as green wood removed from the forest , high in moisture , and with a chemical formula close to cellulose $(C_6H_{10}O_5)^5$.

Biomass Transport.

Costs of transport vary considerably depending on four factors: load density, regularity, load and unload conditions, and distance. In many cases, transport costs are the largest contributors to the overall cost of biomass energy production , whereas in other cases transport costs are relatively small. Because of the bulk, wide distribution, and high water content of most raw biomass resources, however, the rupee, energy, and social costs of transportation should receive careful consideration in sizing and in siting biomass facilities; in many cases it may be most efficient to utilize energy produced from biomass at the growth and harvesting site . Transport costs decline with distance, but most of that decline may occur in the first 40 Km.

Additional transportion requirements may arise due to regional imbalances in biomass energy supplies and local energy demand.

The transportation requirements interact strongly with other aspects of biomass utilization systems, including harvest, storage, and conversion. Densification and modularization for easier handling, as well as drying and other procedures, have been areas of some interest and experimentation. In addition, handling of transportation systems may lead to a veriety of secondary effects, including either increased suburbanization of rural areas and cultural homogenization or growing disparities between rural and urban cultures.

Biogas.

By itself, the collection of animal wastes for energy production will entail neither an increase in the amount of land devoted to feedlot operations nor a change in land-use practices. The current trend toward larger and more numerous commercial feedlots could be reinforced by economic changes related to energy self-sufficiency and by possible new income from the sale of natural gas. It is extremely unlikely, however, that production of gas alone would cause large-scale industrial expansion.

Competition for use of manure for other purposes is more apparent than real under current circumstances. ~~In~~ Thus, use of manure for fertilizer would be no more economically feasible than using it for fuel production. In addition, generation of methane by anaerobic digestion of manure would not preclude its value as a fertilizer or feed supplement because usable nitrogen, protein, and other substances remain in the treated sludge. This is not true of other conversion technologies such as pyrolysis. Digestion is therefore ~~viw~~ viewed by some agricul-turalists as the only viable process for fuel recovery from manure . Use of the sludge for other purposes would also be beneficial in waste disposal, and the costs of sludge distribution might be partially offset by the added value of the raw material as a dig feedstock. Adequately digested sludge materials do not have an offensive odor and in this way are superior to untreated manure, especially when disposal is by land spreading. Flies and other pests are also less attracted to digested wastes, and pathogenic organisms are destroyed in the digestion process.

Impacts on Environment

Water pollution from animal feedlots is related to such factors as the number of animals in the confinement unit, waste production per animal, frequency of cleaning, and characteristics of the wastes.

The degree to which adjacent water bodies are affected is a function of ambient temperature, magnitude of rainfall, slope and drainage of the area, type and area of lot surface and types of management practices. Feedlot runoff, which is rich in nitrates, ammonia, bacteria, chemicals fed to cattle, and other pollutants, may be 10 to 100 times more concentrated than raw domestic sewage. Under certain circumstances, feedlot runoff may affect groundwater as well as surface water by percolation, especially where aquifers are shallow and lie beneath sandy soils.

The use of manures for anaerobic digestion would not necessarily alleviate these water pollution problems. In so-called "environmental" feedlots, animals may be kept in covered facilities in which manure immediately passes through floor gratings to a collection site beneath the animal housing area. Highly efficient collection of this sort would certainly facilitate the use of manure for digestion but digestion need not depend on any special collection method. In many older feedlots, manure will still accumulate in a widespread outdoor layer and thus may be subject to runoff before periodic collection.

Anaerobic digestion also does not eleminate the problem of waste-water disposal. A volume of wastewater comparable to that of the raw material will remain. This liquid effluent is still high in BOD, is not acceptable for discharge to surface waters, and will require treatment, storage, and handling. In any case, the problems encountered in such treatment and handling, to-gether with the impacts of waste disposal, should be no worse than those under current management.

In summary, collection of manure for methane production is one of the most promising of the proposed uses of biomass for energy, especially from an environmental point of view.

OUR COMMENT

Next Fuel Crisis - Firewood Scarcity.

Scarcity of oil has pressed developed nations to seriously think of coal or wood as alternatives. Rising prices of kerosene, diesel, furnace oil etc. has urged developing nations, especially those who do not have oil or coal resources, to use firewood and other agricultural waste products to fill their energy gaps. The rate of depletion of Asian timber and firewood resources is so high that those patches have become large enough to be visible to orbiting Earth satellites. Figures available on an international scale indicate that more than one third of the world's population depend on wood for cooking, domestic heating in colder climates, and other uses.

It is true that the distribution of oil, coal and gas reserves on earth is almost uneven; but it has not much helped the developing countries around the world, with the notable exception of OPEC (Organisation of Petroleum Exporting Countries).

Since high oil prices are already threatening the economics, and acting as a barrier to the technological advancem- of developing countries, their future energy problems are going to be serious. In order to brighten this gloomy future of energy supplies in Sri Lanka, she has to exploit her wood and forest resources extremely carefully, because it has been the only natural fuel and timber source throughout the history.

It has been found that a major problem in the lands of tropics is the continous cutting and clearing of native forests to pave the way for advancement. Clearing forests are caused for the sake of agricultural programmes, strategic purposes, industries, housing schemes, highways, railways and bridges, colonies, people to shift to arable land etc.

In certain undeveloped areas of the world, it has been found that trees of large diameter trunks are "less valuable" than "cooking-stove sized" ones. The poverty in these areas governs that they do not have the means such as saws, wedges and other implements required for the wood felling and cutting etc.

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This is a threatening problem to the small plants, and hardly any plant may grow to its size.

Hard-to-afford petroleum prices, or the total inavailability of fossil fuels in certain developing areas of the world is contributing to deforestation. Ruthless cutting of forests in some countries has lead to critical problems in preserving the natural resource, which otherwise could have been satisfactorily converted to renewable resources by intensive management. Haiti is cited to be in the most serious jeoprady. During the war period in Vietnam certain forests areas were devastated by warfare.

OPEN STOVE

The very low efficiency of an open fire cooking, or three-stone type of common cooking stove in many homes in Sri Lanka, is due to the immediate flow up, or convection, of hot flames erupting from the burning. A very small area of the hot flame is "touched" by the pot on the fire. Heat losses by radiation are high. The hot gases going up carry more than 90% of the heat from the fire without the possibility of being recycled. A pot on an open fire can get only less than 10% of the heat produced by the fuel: firewood or charcoal. Improved versions of firewood stoves, equipped with hot gas recyle, is said to run at efficiencies as high as 20%. But their not-so-simple nature and hard-to-afford costs in developing countries is an obstacle to make them popular. However, due to commercial reasons, the efficiency of simple and cheap, but highly efficient, cooking stoves should be a must under the present energy situation.

Firewood, or fuelwood, is consumed in Sri Lanka, mainly in the rural and urban areas for a large number purposes other than for cooking. Drying or processing of agricultural products, brick, tile and lime kiln firing, clay pottery, illicit alcohol distillation, hot water for sanitary and laundering purposes, bread baking, sweets and confectionary preparation, tea and coffee stalls, black simthery, ayurved preparations etc. demand firewood in large or small quantities. In remote areas, where oil may be a scarcity due to possible transport, geological or economic problems, people are compelled to burn firewood for nocturnal illumination, and driving away wild animals. ....../

Thermochemical Conversion and Environmental Pollution.

Because the thermochemical conversion of biomass includes a variety of technologies and feedstock materials a wide range of emissions is to be expected. Little direct information exists that describes the effluents from thermochemical conversion. Some possible effluents and emissions are described in connection with the full-scale facility descriptions. Additionally, specific effluents that may be associated with a particular feedstock are described
This section discusses studies of known effluents from existing technologies that use biomass (though not necessarily for conversion to energy). In particular, the effluents in wood smoke are described, because smoke can be associated with the thermal processing of almost any cellulosic material.

Smoke.

Smoke is commonly emitted during biomass conversion, but little information on the characteristics of this smoke is available. However, wood smoke (especially hardwood smoke) has been studied in some detail in the laboratory (King 1975; Einhorn et al. 1973; Doerr et al. 1966; Jahnsen 1961). Smoke from other biomass materials may not be different from that of wood, but this fact will need to be confirmed. Two types of studies were encountered, those that focus on hydrocarbons in wood smoke and those that examine carbon monoxide and smoke. Health effects are implicated in each.

Wood smoke is a complex mixture of solid particles, condensed liquid particulates, and volatilies and is produced most abundantly by combustion of moist wood in a restricted flow of air (Jahnsen 1961).

Wastewater effluents from the wood-products industry.

In the absence of direct data on wasterwater effluents from biomass conversion technologies, guidelines for control of wastewater effluents from the wood-products processing industry (Thomson 1976) are useful for examining possible effluents from the preconversion portion of biomass conversion technologies. For example, wet storage of logs produces floating solids in the holding stream, in addition to tannins and other wood extractables.
Log washing and debarking results in suspended solids and biological oxygen demand (BOD). In addition, water or steam in contact with wood or wood products leads to an aqueous discharge high in BOD and phenols (Thomson 1976).
Inasmuch as wastewater effluents from the wood products industry are treatable using conventional water treatment methods, it is expected that wastewater from thermochemical processing of biomass will also be treatable.

COPPICING

Europe is having experience, at least for the last thousand years, in managing forests satisfactorily while extracting firewood, and even timber. This is a nice example of a big excercise because in cold climates a lot of wood had been burnt to heat homes throughout a larger part of the year, other than for cooking. While plant growth rates are slower in cold regions than in tropics, firewood consumption had been comparably high in cold countries than in the tropics.

Because in Sri Lanka we do not use firewood for domestic heating, except for very rare instances in upland areas, and we have enough sunshine and rain to have forests or woods for firewood, any future firewood scarcity can be reduced by means of neat and accurate reforestation programmes, Rear-a-Tree programmes, and mainly by timely and accurate management.

It has been shown, that by the way of coppicing, some forests in Europe had been elegantly handled for at least a thousand years. Coppice farming has been a major triumph in the European and US way of overcoming firewood problems. In coppicing, instead of totally toppling, the tree is cut at a level so that the stump can survi e and produce shoots. Certain types of forests in Europe lasted for nearly three hundred years despite the coppicing every 10 to 11 years.

Coppicing trees to get firewood, and sometimes timber too, has big advantages. Shoots grow vigourously because of deep run roots the mother tree, they suck up and distribute to earth surface valuable nutrients in the deep soil; lesser care is required for coppiced trees than for seedings or small plants. Unlike in the case of totally uprooting trees, coppicing reduces the erosion of land. Certain trees coppice vigourously only two or three times, and yields of wood go down in the next coppice.

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Trees for firewood are programmes that normally does not exceed 10 years. Most of them could be 5-7 years duration. The time has come that trees for firewood, forage or timber should be grown in home gardens, shelter patches and parks, fences, cemetries, near bus halting places where possible etc. School gardens and farms, play ground fencing, along fences, and road sides are potential places for growing trees for firewood and timber, as far as propaganda and educating people are concerned. Traditionally, the impulse of an international crisis goes to the rural folk last. Unlike the urban citize , often he is the least vulnerable on such matters. But that caused by rising prices of kerosene, which is largely used in rural areas of developingg countries, has given well perceptible impact to the villagers. Despite the fact that many Rear-a-Tree or tree planting campaigns are catapulated to the international stage or public arena, often expected results are not achieved in lesser developed lands. Records light to the fact that or tree planting programmes are successes when people who are affected by them are involved with.

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