State of art in utilization of agricultural residues and identification of priority biomass energy projects in the republic of Korea

Soon-Chul Park, Jin-Suk Lee*, Jae-Kyung Cho, Jong-Joon Hong
Biomass Research Team, Korea Institute of Energy Research
P.O. Box 5 Daeduck Science Town, Daejeon, Korea

I. Introduction

Although the importance of agricultural sector decreased over the last several decades because of the economic growth in Korea led by the development of manufacturing sector, the biomass energy resources such as urban wastes, industrial wastes including agricultural residues emerged recently as a major target of development mainly because of environmental issues.

Rapid growth oriented industrial development accompanied by urbanization changed the agricultural sector as much as the other industrial sector. The structure of agriculture should be changed to support urbanization. Agricultural operations mechanize, use more commercial fertilizer and submit more of their output to processing, and transportation to let food supply to urban area. All of these operations requires energy not used in traditional agriculture. Consequently, the agricultural residues rapidly loses its values as energy sourses or as fertilizers (compost), because of their relatively lower quality in comparison with the modern versions and their labor intensive nature for utilization. Most of the residues simply became wastes even in rural areas nowadays.

Recently, as the environmental problems such as massive waste generation and the global warming because of the excessive use of fossil fuels became hot issues worldwide, the utilization of solid waste including agricultural residue as energy sources draws renewed attention. However, to incorporate these primary energy sources into existing modern energy demand structure of Korea, it is imperative that we focus on the efficient conversion and use of biomass so that it can provide modern fuels such as gas, liquid fuels and electricity in addition to the more traditional and obsolete role as a heat supplier in the form of firewood in rural household sector.

In this context, the availability, present utilization and future propect of the utilization of agricultural residues including biomass in Korea will be described.

II. Availability and Utilization of Agricultural Residue and Biomass

Biomass differs fundamentally from other forms of energy because of the diversity of types, production and use techniques, its quite site specific availability and seasonal fluctuation. Therefore, like many countries, Korea has never had any official data about the availability of biomass energy sources except for the firewood from forest. Although biomass utilization in consumption side has been estimated quite correctly in the previous analysis, the specific types of biomass has not been shown. This lack of biomass resources data is partly due to the small share of biomass energy in Korea (1.4% of total). In addition since firewood is ordinarily produced by an individual and consumed on site for himself, the estimation is believed to be practically impossible. However, having reliable information on biomass production and use is essential if resources are to be sustainably managed to provide traditional and modern fuels originating from biomass.

A. Residues from Forest and Lumber Industry

A statistics of forest products used as fuel in the year 1989 in Korea is tabulated in Table 1.

Table 1. Fuel production from forest in 1989

Names of products	Quantities (Unit : MT)
Firewood	303,174
Charcoal	1,321
Leaves and branches	1,282,205
Others	503,651
Total	2,090,351

From Table 1, total wood biomass produced to be used as fuel was 2,090,351 metric ton, this quantity approximately corresponds to 904.6 Th-TOE by simple calculation. If we remind that firewood (general terms including branches etc.) utilized in the 1989 was estimated to be approximately 856.7 Th-TOE from consumption side, it is believed that the firewood was supplied in surplus from the forest only. This fact is natural since Korea nowadays has sizable forest growing stock (2 billion m^3) relatively well preserved, and firewood from forest has normally higher qualities than that produced as agricultural residue. Moreover, most of Korean rural residence has mountains and forest nearby.

The amount of forest wood residues which will be produced naturally is accounted to be about 6 million in a year and only about a third was utilized as fuel in the year 1989.

On the other hands, the quantity of non-forest residues produced from industry (normally using imported lumber) was estimated to be 860,000 m^3 in the year 1991. Most of the residue is recycled on-site as fuel (50%) and as raw materials for wood products such as particle board, pulping etc. Sawdust is used as packing material and bulking agent for packaging and composting, and part of it as a raw material for carbonized saw-dust briquette (used as an ignitor of coal briquette) or activated carbon production.

B. Agricultural Residues

In 1988 the amount of agricultural residue produced was estimated to be about 11.8 million MT from crop production data. As shown in Table 2, rice straw and rice hull occupied about 82% of total agricultural reidues produced in a year.

Table 2. Agricultural residues produced in 1988 in Korea

Residues	Amount produced (1000MT)	% of total
Rice straw	8,228	69.5
Rice hull	1,487	12.6
Barley straw	560	4.7
Misc. grain residue	141	1.2
Pulse residue	444	3.8
Special crop residue	328	2.8
Potatos residue	187	1.6
Fruit production residue	468	4.0
Misc.	-	-
Total	11,843	100.0

1) Misc. grains : corn, millet, sorghum etc.
2) Special crops : sesame, perille seed, rape seed etc.

On-site actual survey on the utilization of agricultural residue was not implemented nearly a decade after 1980 in Korea. Hence, the utilization pattern data in 1980 will be quoted in Table 3.

Table 3. Utilization pattern of agricultural residues in 1980

Utilization / Residues	Com-post	Animal Feed	Fuel	Market Sale	Waste	Misc.	Total
Rice straw	53.1	26.6	11.6	2.1	0.3	2.9	100
Rice hull	66.2	1.3	30.2	0.5	0.4	1.4	100
Barley straw	68.5	2.3	25.2	0.1	0.6	3.4	100
Misc. grain residue	18.0	38.5	14.4	28.2	0.9	-	100
Pulse residue	10.1	29.2	59.8	0.3	0.5	0.1	100
Special crops residue	5.2	8.0	70.6	0.1	15.4	0.7	100
Potatos residue	18.1	76.0	0.6	0.6	3.3	1.1	100
Fruit product. residue	-	-	100.0	-	-	-	100
Misc.	1.0	0.2	97.6	-	0.8	0.2	100

Some numbers in the table have significances. Large part of grain straw and rice hulls were utilized as compost for the fertility of soil. All the fruit production residue was used as fuel because it is the branches trimmed. High percentage of pulse residue and special crops residue such as sesame stems was used as fuel probably because of its relatively high quality as firewood in comparison with other uses. Since reliable utilization pattern data of agricultural residue in Korea is not available recently, it is believed that greater portion of residues are recycled in the soil as compost or wasted in the field now. Practically very small part of residue is believed to be used as fuel. However, the data in 1980 (Table 3) can be estimated as an approximate base of potential available agricultural residue which can be used as fuel. The amount of residue utilized as fuel, wasted and used as miscellaneous purposes were estimated to be the potential biomass resources as shown in Table 4.

Table 4. The potential agricultural residue which can be used as fuel in 1988 based on the utilization data of 1980.

Residues	Amount available(1000MT)	% of total amount	Energy content(Th-TOE)	% of total enrgy
Rice straw	1217	41.9	419	39.0
Rice hull	476	16.4	165	15.4
Barley straw	163	5.6	56	5.2
Misc. grain residue	21	0.7	9	0.8
Pulse residue	268	9.2	110	10.2
Special crop residue	284	9.8	110	10.2
Potatoes residue	9	0.3	3	0.3
Fruit product. res.	468	16.1	202	18.8
Misc.	-	-	-	-
Total	2,906	100.0	1,074	100.0

Table 4 shows that rice straw, rice hull occupies 58% of available resources. Among the resources available, only the rice hull was systematically developed as fuel in the form of rice hull briquette. The rice hull produced from the large scale mill is extruded as briquette is used as heating fuel in the school, in the small scale commercial facilities. The production increases gradually as shown in Table 5 with technological improvements of extruder and combustion equipment by R&D efforts.

Table 5. Production of rice hull briquette in Korea.

Year	1985	1986	1987	1988	1989	1990	1991
Production of rice hull briquette (MT)	45,000	66,650	66,000	70,000	72,000	85,000	90,110

Since the heating value of the briquette is 4,100 kcal/kg, the quantity produced in 1991 corresponds approximately 37 Th-TOE of energy

Therefore, about 22% of available rice hull was utilized as fuel. The relative success of rice hull briquette in Korea is probably due to the following factors.

- An alternative use of rice hull is not available yet (slow composting, inadequate as animal feed, large volume weight ratio etc.)
- Easy collection because of large scale milling of rice in Korea
- Presence of consummer in public sector (schools, small scale commercial sectors such as market places etc.)

C. Livestock Production Residue

Livestock production residue became potential energy resources after several socioeconomic changes and technological innovations.

- Increase of livestock products consumption because of income increase, and increase of the number of full-time large-scale livestock raising households.
- Requirements of livestock residue treatment for water pollution abatement.
- Improvement of anaerobic digestor, methane production and utilization technologies.

Residue of full-time livestock raising households in 1989 is summarized in Table 6.

Table 6. Residue of full-time livestock raising household in 1989 and its energy contents

Animals	No. of Head	kg residue /head/day	Annual sum (1000 MT)	Energy Content (Th-TOE/Y)
Beef cattle	789,173	40	11,521	2059.4
Dairy cattle	390,222	45	6,399	1143.8
Swine	4,189,072	45	6,870	1511.4
chicken	55,124,000	0.1	2,039	504.7
Total			26,831	5219.3

The utilization of small scale anaerobic digestor in individual rural household is not popular in Korea. A government promoted project was disclosed to be complete failure because of cold winter, seasonal fluctuation of methane demand and especially inadequate residue supply and maintenance by farmer.The methane requirement for cooking and heating does not depend upon the production of residue from animals.
However, recently 47 of livestock residue digestors of approximately 10 m^3 to 100 m^3 reactor capacity (total 2583.5 m^3) was constructed and produced methane corresponding to 680 TOE per year. On the other hand, according to the goverment enforcement for the water pollution abatement, 25 of food industry residue digestors, which have 98,309 m^3 reactor capacity, produced 25,830 TOE of energy.

III. Biomass Conversion Technologies in Korea

A. Methane from organic wastes

The digestor used in the system shown in Fig.1 was an improved version of conventional digestor improved in its internal sludge recycle . Recently organic waste of various organic loading including municipal solid waste and industrial organic waste water are tried to be treated with various advanced digestor technologies. The development of high organic loading two-stage anaerobic digestor (20-30% Volatile Solid) for municipal waste and those of high rate anaerobic digestor such as UASB(upflow anaerobic sludge blanket), AF(anaerobic filter) for various industrial waste water shows the typical examples. In accordance with the growth of the livestock raising industry in Korea, these advanced technologies is believed to be continuously developed and applied extensively in the future.

B. Ethanol from lignocellulogic biomass

The production of ethanol has received attention over the years as a neat liquid fuel for transportation sector and octane booster. In fact, major production plants operate in both Brazil and the US for manufacturing ethanol from sugar cane and corn respectively. Brazil produces over 15 billion liters, and in US about 3.2 billion liters of anhydrous ethanol for neat ethanol or gasoline blend.

However, fermentation stoichiometry reveals that many feedstocks including sugar cane or corn are expensive for fuels production even considering co-product credits and ignoring conversion costs, whereas lignocellulosic feedstocks such as agricultural or forest residue, and cellulosic municipal solid waste cost much less than those. Furthermore, the quantities of lignocellulosics are projected to be large in Korea. An estimation made by our laboratory predicted 700 million metric tons of this a year and this amount corresponds 1.1 billion liters of ethanol a year. This can cover around 17% of current gasoline consumption a year in Korea .

Therefore, in parallel with two ethanol pilot plant project of 1,000 liters a day from carbohydrate of imported cassaba etc., an 20 liters per day bench-scale ethanol plant project is on-going in our laboratory. A schematic process flow diagram of the plant is shown in Fig.2. This bench-scale plant will be used as a facility for the testing of improved technologies of ethanol from lignocellulosic biomass.

C. Heat recovery from municipal solid waste

Because of rapid urbanization and dense population of Korea, the amount of municipal solid waste including those from rural area increased 8 - 9% a year. Over 90% (92.5% in 1988) of municipal solid waste is disposed by landfill, but landfill site with few exception experience the saturation already. Therefore, the recovery of heat from combustible waste (about 46.3% of total) produced about 34,000 metric tons a day nation wide is urgently needed. And the incineration and heat recovery means about 11.7 million TOE of energy saving nationwide. The development of efficient incinerator is also involved in the new and renewable energy development project.

A 200 ton per day incinerator with our own technology is mid-term target of this project until 1996. In long-term projection, 20 to 30% of municipal solid waste is planned to be incinerated, and heat will be recovered from it.

IV. Significances and Suggestions

Even though the biomass utilization in Korea declined for decades, it needs to be recognized that there is a substantial untapped biomass potential in improved utilization of existing forest and agricultural residues, and in heat recovery from municipal solid wastes. The available biomass energy was shown to be 2,700 Th-TOE from forest, 1,074 Th-TOE from agricultural residue and 5,219 Th-TOE from livestock residue. If all these residues could be utilized appropriately about 14% of Korean energy supply can be covered by biomass energy. In addition, there is enormous municipal solid waste freely available from which heat can be recovered. However, it is essential that greater effort is put into converting and using biomass efficiently than producing it.

The traditional use of biomass are declining in Korea. But long term perspectives are complex, the complication in determining these future developments is due to the fact that traditional energy use is tied to a number of socio-economic factors outside of the energy sector. A large part of present and future use will be non-commercial and therefore outside of normal market forces.

Hence, wider commercial application of biomass energy on a sustainable basis awaits the development and application of modern technology to enable biomass to compete with conventional energy carriers. Biomass can be converted to solid fuel as rice hull briquette, liquid fuel via alcohols or gases and electricity via digetor, gasifier and gas turbines. Biomass can serve as a feedstock for direct combustion and is easier to upgrade than coal because of its low sulfur content and high reactivity.

Modern biomass technology offers a very significant potential for increased energy production and substitution of conventional energy resources. In addition such a transition could have significant environmental and socio-economic benefits since biomass is renewable resources.

In order to realize the future potential a number of actions have to be undertaken on local and international levels, including information and data exchange, R&D of biomass technology and economic and institutional measures for biomass energy. Korea already started its efforts to develop the biogas, ethanol and municipal waste incinerator and had experiences in conventional technology such as rice hull briquette. An international cooperation between nations with various bioenergy experiences and site specific problems will serve as a good opportunity for the extensive exploitation of biomass energy, a sustainable and clean energy source.

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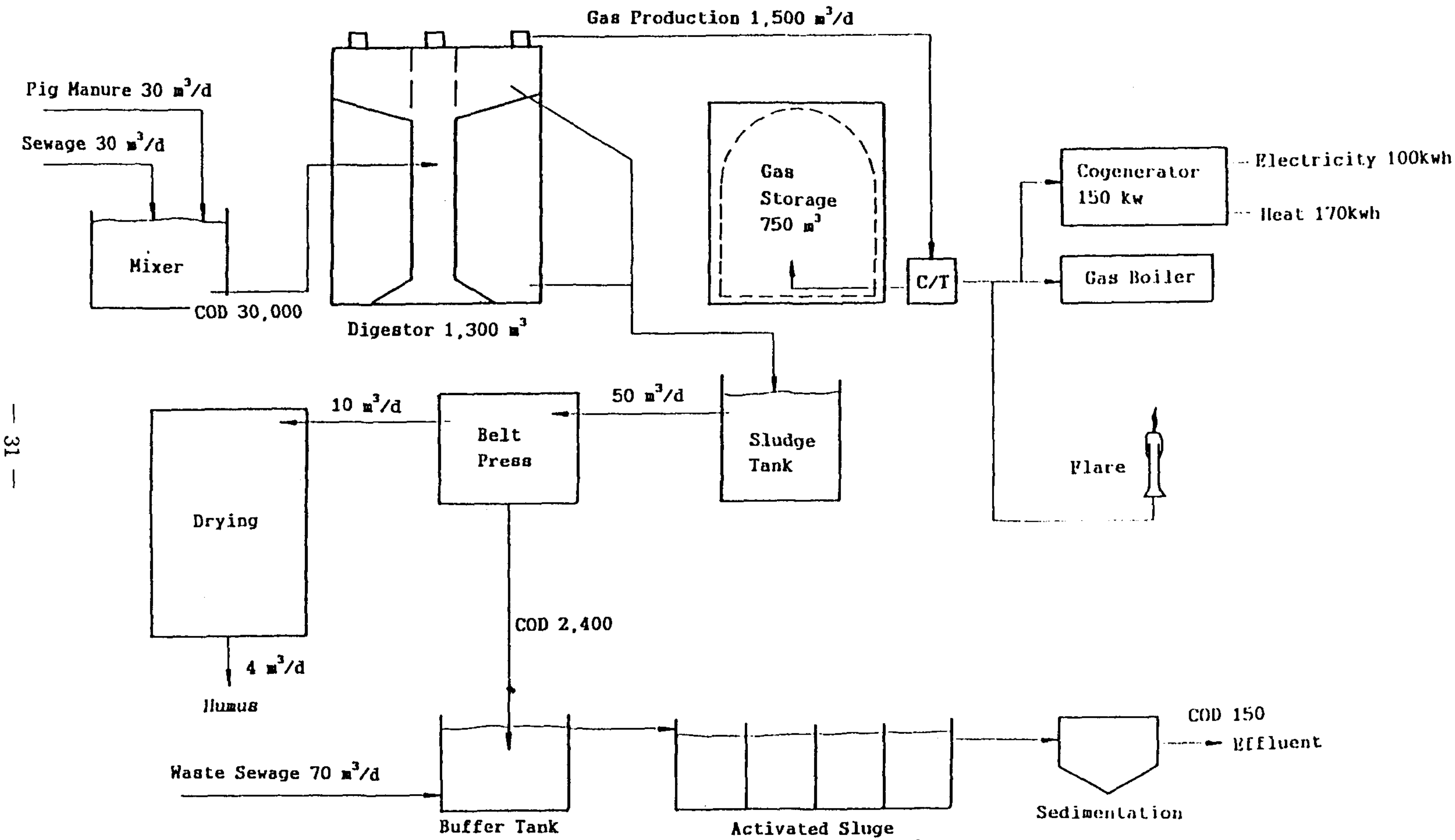
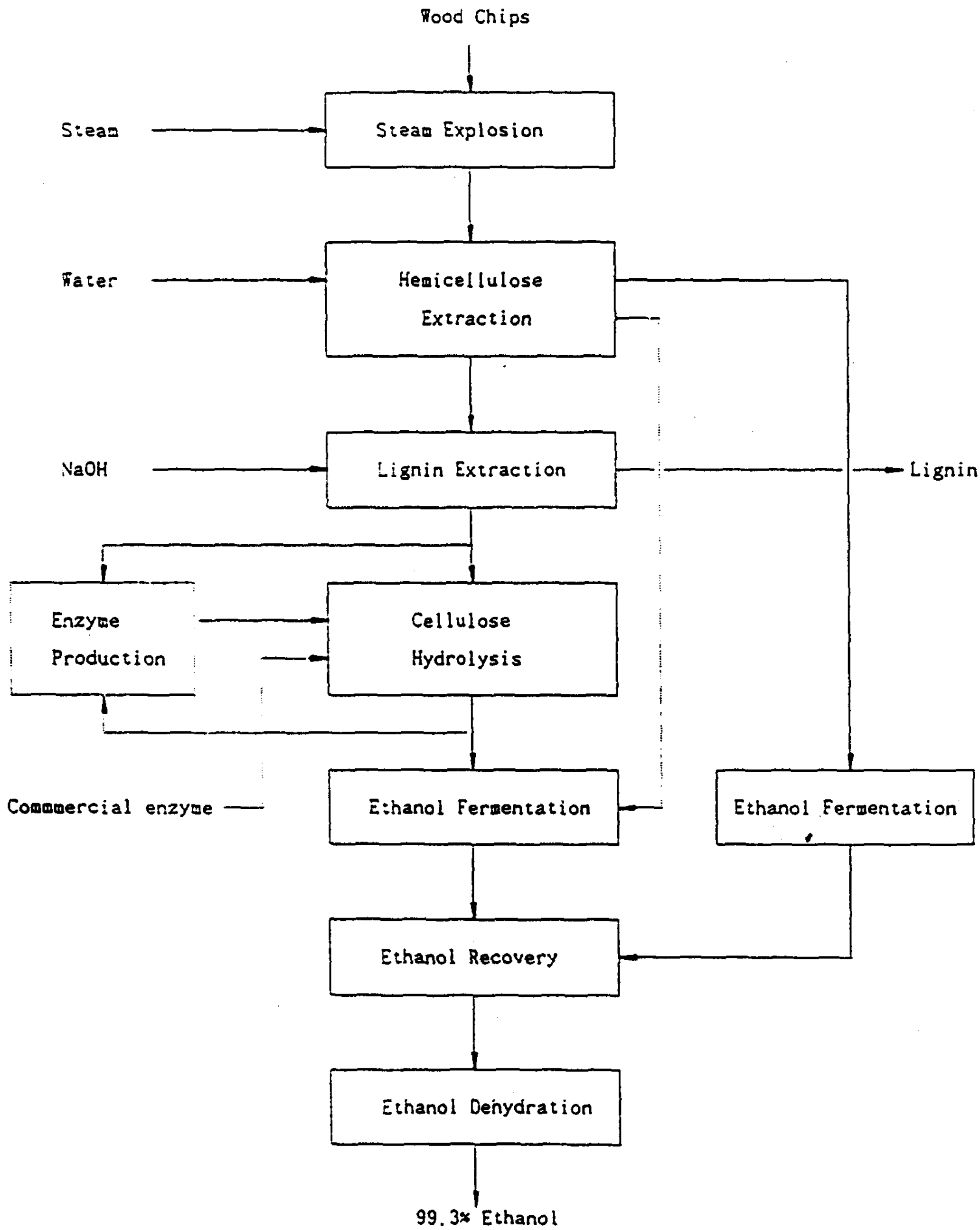


[Fig.1] Typical livestock residue anaerobic digestor system in Korea



[Fig. 2] Process of ethanol from lignocellulosics