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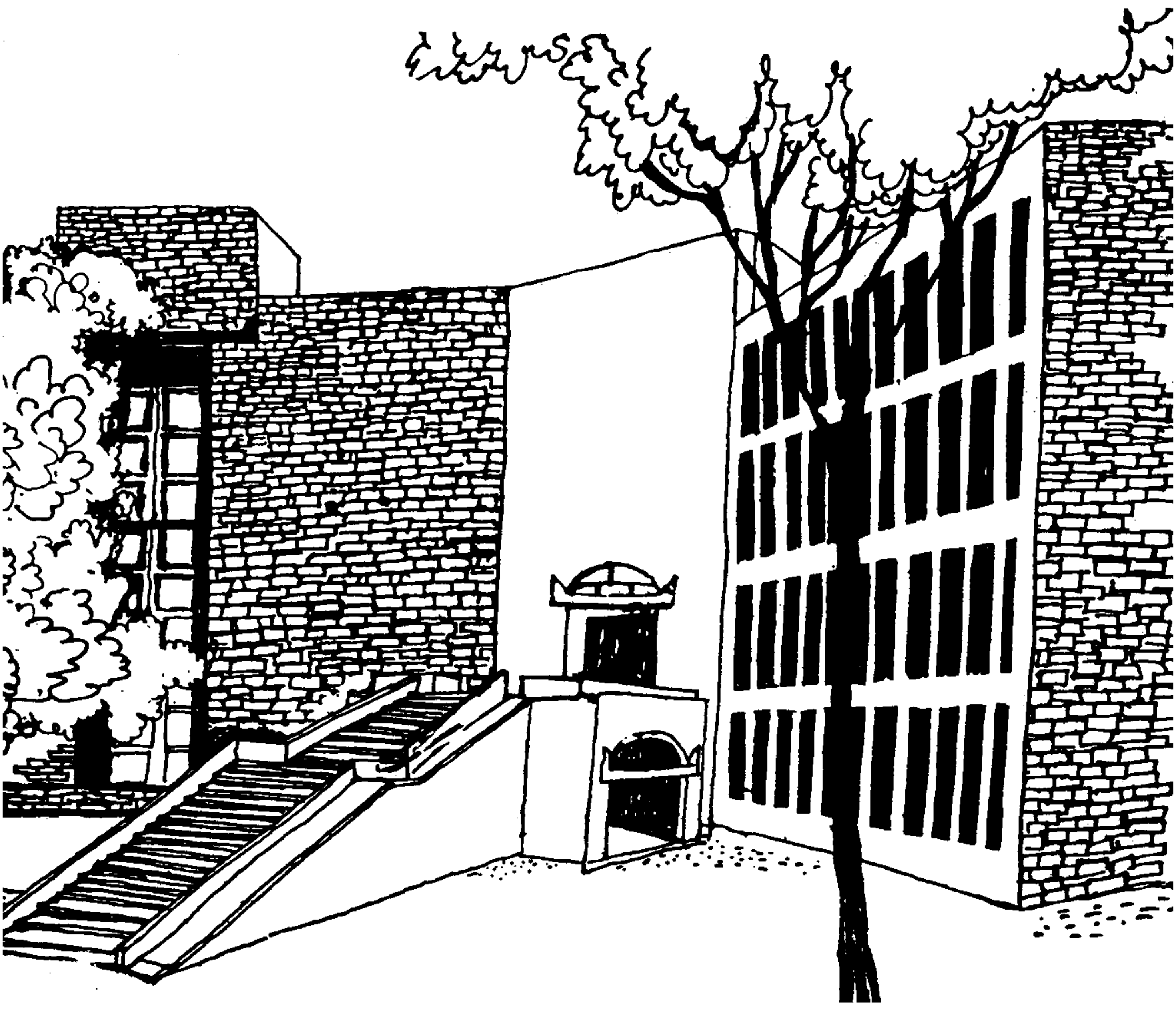

ESTIMATING BIOMASS POTENTIAL FOR BIOFUEL CONVERSION IN INDIA: SOME METHODOLOGICAL ISSUES

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W P No. 1001
January 1992

The main objective of the working paper series of the IIMA is to help faculty members to test out their research findings at the pre-publication stage.

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ABSTRACT

As resources diminish and needs increase, it has become important to utilize waste materials as fuel. This paper discusses some methodological issues on the biomass conversion into fuel. Biomass is an organic matter formed by plants, trees, agricultural crops, crop residues, and by-products of forestry and agricultural industries. Utilization of indigenously available biomass resources can reduce the production cost and alleviate the problems of disposal and pollution.

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The Problem

Potentially all biomass produced in a country can be used as fuel either by direct combustion or after being subjected to some bio-fuel conversion processes. There are essentially two bio-energy conversion technologies: biological and thermal processing. The fuel potential of biomass and some well-known conversion processes involved is shown below:

Table 1: Biomass Conversion Techniques

Process	Biomass Inputs	Output	Approx. Overall* Efficiency
1. Direct Combustion	Dry**	Steam	65%
2. Gasification with O_2	Dry**	Electricity	25%
3. Gasification with air	Dry**	a) Medium Btu gas b) Steam	60% 65%
4. Pyrolysis	Dry**	Pyrolytic oil, char and L.B.G.	45%
5. Anaerobic Digestion	Aquatic biomass, and sewage sludge	M.B.G and methane	50%
6. Ethanol Fermentation followed by Distillation	Molasses, sugars, hydrolyzed cellulose	Ethanol	30%

*50% moisture allowable without drying

**% of biomass input (HHV) converted to fuel (for steam) less the required internal fuel needs of the conversion process.

Source: John R. Benemann, "Bio-fuels - A Survey" (June 1978)

Obviously, the bioenergy conversion technologies as mentioned above can utilize a wide range of biomass produced in a country. There are four categories of biomass which could be considered as feedstocks for bioenergy conversion processes: crop residues; silvicultural biomass or forest residues; municipal and industrial wastes or sewage; and animal wastes.

Assuming that there are no technological and economic limitations, what is the potential amount of biomass feedstock for bioenergy conversion in India? The most important limiting factor in estimating the potential biomass feedstock in India is the existing competing needs and end-uses of the biomass. Considering this limitation, only municipal and industrial wastes could be considered as easily estimable amount of feedstock for bio-energy conversion in India, which do not have any significant competing end-uses and therefore could immediately be utilized. The problem of estimation lies with the other three groups of biomass. For all of them meet varying degrees of competing needs and end-uses such as fuels, fertilizer, fodder, construction material and other domestic/social uses. In making a claim upon these biomass as feedstock for bioenergy conversion, their competing end-uses, and possible substitution or replacements have to be assessed carefully.

Closely related to the above mentioned limitation of competing end-uses, there is another critical factor associated with bioenergy conversion in developing countries like India. In the prevailing socio-economic conditions in India, the competing needs including fuel need for a large masses of people are met by biomass resources which are most often a free supply (collected or gathered) or at a zero private money cost. Apparently, a large proportion of the population dependent on the "free-of-cost" biomass resources for meeting their competing needs is the poor with negligible or almost nil purchasing power. It is true that the "free-of-cost" supply of biomass has been increasingly becoming difficult and even notional, given the increasing labour-time cost for collection or gathering, the fact remains that given the opportunity, cost of labour time, its supply is still perceived to be cost-free by a large majority.

On the other hand, bioenergy conversion of available biomass would certainly change the existing socio-economic equilibrium, even though it is energy-efficient. The converted bio-fuels with its capital investment would inevitably tend to create a commercial market for its feedstock as well as market-segments for its output i.e. biofuel. In fact, it is possible to imagine a situation in which the biofuels produced by conversion technologies with feedstock supply from rural hinterlands would be sold in a renumerative urban/semi-urban/industrial markets at the expense of poorer households in the rural areas. Given the very low or almost nil purchasing power, a large mass of poor rural households may tend to suffer grievously. In estimating the potential biomass feedstock for bioenergy conversion in India one has to take serious note about this limitation as well.

Some Estimations

Having briefly outlined the two basic limitations, it is possible now to critically examine some of the estimations of biomass potential in India made by various authors in the recent past. In this we will particularly look into the issues related to agricultural or crop residues only.

First, let us take the estimates made by the Working Group on Energy Policy (N.B. Prasad Committee), 1979. Total estimated crop waste for the year (1975-76) was reported to be about 200 million tonnes broken down as follows:

Table 2: Crop Waste Production (1975-76)

SL. NO.	Crop	Estimated crop waste (1000 tonnes)
1.	Rice	77984
2.	Wheat	50480
3.	Sugarcane	28121
4.	Maize	8707
5.	Barley	4788
6.	Cotton	3036
7.	Jute	1510
8.	Other crops	28926
	TOTAL	203552

The important observation to be made here is the fact that the Committee also pointed out that only about 50 million tonnes of the 200 million tonnes were used as fuel. In other words, only $^1/_4$ of the total available crop residues were reported to be used as fuel, while the remaining $^3/_4$ had either been used for other-than-fuel competing uses or simply as non-utilized wastes. It is therefore surprising that almost all subsequent estimations of biomass fuel potential for fuel-conversion in India, not only tend to be highly optimistic but also ignore the fact of competing uses. In fact, the bio-fuel enthusiasts have been claiming a potential of more than 200 million tonnes of biomass per annum with complete disregard to the existing end-use pattern. One such recent estimate is shown below:

Table 3: Major Potential Biomass Resources*

Material	Annual Availability (Million tonnes)	Coal Equivalent Energy Value (MTC/yr)
1. Rice straw	90.0	58.4
2. Rice Husk	19.9	15.7
3. Jute Sticks	2.5	2.3
4. Wheat straw	50.0	37.5
5. Cotton stalks, Linters and Hulls	13.0	11.0
6. Bagasse	28.1	22.4
7. Coconut Husk & Shell	1.0	1.1
TOTAL	204.5	148.4

*Source: T.K. Ghose and Bisaria, V.S. "Biomass - An Alternative Energy Source", Science Today, August 1984.

It should be noted that the above estimates do not include maize, barley and other miscelleneous crops as in the Energy Policy Committee Report.

What is even more interesting to observe is that there are still more robust estimations made by some Indian authors. Paul (1981), for example, emphasized the inclusion of water hyacinth as the potential biomass, which with its 0.5 million hectare area in Eastern India alone could yield 200 million tonnes of biomass per annum. In fact, in most popular writings in India, a figure of 500 million tonnes is often mentioned as the estimated available biomass per annum for potential biofuel conversion (which includes agro-industrial wastes also).

However, it should be mentioned here that the estimated total annual production of 500 million tonnes of biomass out of agricultural residues may not be as inaccurate as it seems. This, of course, means inclusion of water hyacinth, grasses, residues from oil-bearing plants like arecanut, cashewnut, coconut, all oilseeds, plantation crops like tea, coffee, rubber, tobacco, various pulses and millets apart from those listed in above tables. The crucial point to be considered is how much of this estimated 500 million tonnes of total biomass production of "agricultural system" in India could be made available for biofuel conversion?

Competing End-Uses

As mentioned earlier, the potential of biomass out of the "agricultural system" to be available for biofuel conversion should be that portion which does not disturb the competing end-uses other than fuel-use. In other words, our first assumption for the estimation should be that it must not claim on that portion of biomass production which is presently meeting some competing needs in the social system. This should not be a difficult problem if we know the existing end-use patterns of various biomass. There are some estimates available on all-India level for certain crops, which might be sufficiently indicative for our discussion.

A Government of India report on the Status of Waste Utilisation Activity in India (1983-84) suggests the following pattern of end-uses for certain agricultural residues:

Table 4: Crop Residues Utilisation Pattern*

Agricultural Residues 1	Present Status of Production and Use (per annum) 2	End-Use Pattern (in%)** 3 fuel	Non-fuel
1 (a) Non-edible oil-seeds (e.g neem, mahua, Karanj and Undi)	With 80 different oil-bearing trees, the estimated annual production of oil-seeds is about 1 million tonnes, of which only 70,000 tonnes are presently collected. The rest is a waste i.e. unutilized. More than 60% of these oilseeds are of neem and mahua. These oilseeds are presently processed in villages or mills into oils and cakes. The oil is used by various industries (soap-making, medicine, insecticides) as well as directly by people (tribals use Mahua oil and Mahua alcohol). The oilcakes are often used as manure or livestock feed (Mahua-cake).	NIL	100%
(b) Edible oil-seeds (e.g. groundnut, mustards, castor, cotton etc.) (i) oil and cake	The estimated production of edible oil-seeds in 1983-84 is about 13.5 million tonnes, of which groundnut alone comprises 50%. Most of these oil-seeds are either processed in mills or home-processed in villages into oil and cake. While the oil is a high-demand household consumption item and mostly used for cooking purposes, the cake is almost exclusively used either as livestock feed or as fertilizers. A part oil and cake production is a high-value export item apart from high demand domestic market	NIL	100%
(ii) shells, Linters and Hulls	About 4.5 million tonnes of groundnut shells are produced annually in the oil-processing sector. More than 60% of these shells are used as fuel in the processing mills, while about 20-25% used as livestock fuel and the rest is waste.	60%	40%

1	2	3	
(c)	About 9 million tonnes of cotton linters with seeds are produced annually. Most of it is used as cattle feed and some for sowing. A very small fraction of linters is used as fuel	Almost Nil	Almost 100%
2 Rice			
(a) Straw	About 80-90 million tonnes of rice-straw is produced annually. A part of the rice straw (about 25%) along with the roots are ploughed back to the soil as organic recycling process. In most of the rice-growing areas in India, except Punjab, rice straw is the basic roughage or cattle feed. A part of it is often used as construction material in thatched roofs. A very small fraction of rice straw may often be used as fuel as a ready starter for direct fire.	Almost Nil	Almost 100%
(b) Husk	Nearly 20 million tonnes of husk is produced annually, mostly in the mills. As much as 70% of the husk is presently used as fuel in the mills itself and households. The rest is used for various purposes, e.g. building materials, packaging, cattle feed, etc.	70%	30%
3 Wheat Straw	There are about 60 million tonnes of wheat straw produced in India in 1983-84. Almost all of it is used as cattle feed, except a negligible portion used for purposes e.g. thatching, organic matter, recycling and waste.	Almost Nil	Almost 100%
4 Tea Waste	Presently a large proportion of tea waste in the order of 8000 to 9000 tonnes is burnt and the rest is a waste.	80%	20%
5 Tobacco Waste	The estimated annual production of tobacco waste is about 62,000 tonnes. Of this $^2/_3$ is used as manure and insecticide. The remaining $^1/_3$ is wasted.	Nil	100%

1	2	3	
6 Bagasse	The quantity of bagasse produced annually is estimated to be about 28 million tonnes. About 85% of this amount is used as fuel in sugar factories and jaggery units and the remaining 15% is used as a mixture with pulp for making paper or hard board.	85%	15%
7 Coconut			
(a) shell	About 0.8 million tonnes of shell produced of which about 60% used as fuel and the remaining 40% for manufacture of fancy and miscelleneous household articles	60%	40%
(b) Husk	About 6000 million tonnes is annually produced. About 50% of it is used in coir industry, while only about 10-15% used as fuel. The rest of it is either wasted or used in various social and household purposes.	10&	100%
8 Arecanut			
(a) Husk	0.1 tonnes available annually, used as a poultry feed	Nil	100%
(b) Leaf Sheath	About 99000 tonnes is produced annually. Like coconut, most of it used as a thatch or making brooms.	Nil	100%
9 Cotton Stalks	Approximately 25 million tonnes is produced annually. Most of it is used as fuel in villages.	100%	Almost Nil
10 Jute Stick	About 2.5 million tonnes available annually. More than 80& used as fuel and the rest for fencing purposes.	80%	20%

*While most of the data in the table is from the Government of India's report, some of the estimates are based on my own surveys.

**The non-fuel use includes wastes or non-utilized.

The above foregoing table clearly indicates the importance of competing non-fuel use of the biomass. In fact, except bagasse, cotton stalks, groundnut shells, rice husk, tea waste, coconut shell and jute sticks, all other agricultural residues mentioned in the table are largely used for meeting non-fuel competing needs. Among all the biomass used as fuel, bagasse and cotton stalks are most important in terms of the quantum and therefore needs to be examined more closely.

As mentioned earlier, a large part of bagasse is used by the sugar mills as a fuel for boilers. For the sugar mills, bagasse burning boilers seem to be cheaper and convenient, even though it might be relatively energy-inefficient. Consequently, the sugar mills are extremely reluctant to convert their bagasse burning boiler. Similarly, in the dispursed large number of jaggery units in villages, bagasse is the readily available and almost free fuel. Thus, in the absence of cheaper alternative, it is unlikely that direct burning of bagasse could be replaced easily.

The problem with cotton stalks is of a different kind. In the cotton growing areas in India, it almost meets 6 months fuel need for cooking, particularly the poor households. Either it forms a part of the wage component for the agricultural labourers or it is given away free after stocking a required reserve for the landowning households. In a survey in a cotton-growing district in Gujarat, it was observed that as many as 40% of the households were completely dependent on cotton stalks as a free supply of fuel for about 4 to 6 months in a year. This brings us to the question of inbalance, as mentioned earlier, if and when commercial biofuel conversion (e.g. pelletization, bricketing or feedstock for gasifier) of cotton stalks is undertaken in such areas.

Macro-Versus-Micro

The foregoing discussion brings us to the crucial question of all-India macro level estimates as against the location-specific micro level ones. It may not be very difficult to estimate the biomass potential for biofuel conversion at an aggregate all-India level. A simple and logical way to estimate the potential would be to calculate the quantum of various biomass used as fuel plus the waste or unutilized portion. It is also possible to project the future trends by taking into several elasticities of demand of fuel and biomass production. However, for estimation of wastes or unutilized biomass, a caution has to be taken about the infrastructural and economic viability of the retrieval of wastes or unutilized biomass.

Be that as it may, the aggregate all-India estimates of biomass potential would remain merely a possibility. To translate it into actual technological interventions through any of the biofuel conversion processes would necessarily require location-specific disaggregated estimates. It is in this micro-level disaggregated estimations of biomass potentials, all the factors, interrelationships and constraints would manifest in full details, which should be captured in a rigorous methodology.

The validity of the methodology for estimating biomass potential at disaggregated micro level would depend on its ability to provide implementable options for technological interventions in location-specific situations. What does it mean in operational terms? Clearly, it would require the following information or data in relation to a particular area or location:

1. A detailed resource mapping of the area with particular reference to biomass producing resources. This should include:

   (a) Cropping pattern including area under cultivation, yield, crop varieties, cropping intensities, biomass content per unit of crop production etc.

   (b) Other biomass residues e.g. grasses, water hyacinth etc.

   (c) Livestock population and estimate of daily yield of animal waste per head. Similarly, an estimate of human wastes.

   (d) Forest and other fuelwood resources.

   (e) Agro-industrial wastes.

2. The existing process and levels of collection and disposal of various biomass giving estimates of biomass utilized for various competing end-uses and those not utilized or not collected or wasted.

3. Socio-economic characteristics of the population in the area with income and expenditure patterns of various socio-economic groups, their levels of biomass use for various competing needs, household expenditure pattern on fuels including types of biomass.

4. Elasticities of demand for biomass for different end-uses in relation to price, income, household size, livestock holding, land ownership, cropping pattern etc.

Given the above mentioned data system it is possible to work out an econometric model (e.g. LP equation) to estimate the maximum potential biomass available in an area as feedstock for biofuel conversion processes under various constraints. Some of the important constraints could be:

(i) No claim on biomass to be used to meet non-fuel needs.

(ii) No claim on biomass to be used as fuel by poorer section (at a certain income level) as free-of-cost supply.

(iii) The price of biomass and biofuel not to exceed a particular limit.

(iv) A limit of total biomass availability due to organisational and economical viability of collecting biomass i.e. allowing a certain level of inevitable waste or non-utilization.

Towards a Methodology

The data requirements for working out a methodology of estimations, as detailed above, seem to be a tall order. However, fortunately for India, there are presently available a large number of detailed location-specific (often village-wise) rural energy survey reports containing most of the basic information. Many more rural energy surveys are in the pipeline. To start with, this survey data could be a valuable base to formulate a methodology of estimation. It may be necessary, in some cases, to update the data base or fill up the gaps by conducting some quick field investigations.

It would be appropriate to test the methodology in an area where one or the other biofuel conversion units are in the process of being set up. There are increasing numbers of such proposals for biofuel conversion units in the process of finalization. In fact, the present author plans to undertake a similar exercise in four agro-climatic regions of Gujarat (subject to financial support), the results of which may be expected to be available within a period of a year.