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A Case Study

Harnessing fuel-energy from biomass for drudgery reduction in rural households

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ABSTRACT : Household sector is one of the largest users of energy in India, accounting for about 30 per cent of total energy consumption, thereby, reflecting the importance of this sector in total national energy scenario. Nearly all rural households and one-third of urban households do not use clean cooking fuel. It is well documented that about 80 per cent of the energy used in rural areas for cooking is derived from biomass, dung cakes and firewood. Women spend 4 to 6 hours of their productive time in fetching biomass / fuel-wood for cooking and carry it as a head-load. Children are also involved in collection of fuel-wood in their school hours. Use of loose biomass as fuel for cooking is the major cause of indoor air pollution in developing countries as it is used in poorly functional wood-stoves. Combustion of biomass leads to high levels of health damaging pollutants such as carbon monoxide, nitrogen oxides, formaldehyde, benzene, aromatic hydro-carbons and many other toxic compounds. Exposure to smoke from burning of biomass fuel is responsible for several diseases such as acute respiratory infections, tuberculosis and asthma, low birth weight, and cataract and blindness, thereby, adversely affecting the health of women and children to a great extent. Therefore, in Indian households, energy problem is not only a problem of the scarcity of energy but also of inefficient combustion and related health problems. Briquetting and pelletizing is an appropriate technology for harnessing renewable fuel-energy from this huge stock of biomass. Conversion of biomass into pellets and burning it in improved pellet stoves can help to overcome the problem of inefficient combustion besides mitigating the health problems associated with smoke pollution. Improving access to this affordable, clean, smoke-free energy is critical for reducing women's drudgery and improving the quality of life in rural areas. This will ultimately result in maintaining sustainable health of the environment and the economy.

KEY WORDS : Biomass, Fuel energy, Pelletizing, Rural households

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Globally, 140 billion metric tons of biomass is generated every year from agriculture. This volume of biomass can be converted to an enormous amount of energy and raw materials. Equivalent to approximately 50 billion tons of oil, agricultural biomass waste converted to energy can substantially displace fossil fuel, reduce emissions of greenhouse gases and provide renewable energy to some 1.6 billion people in developing countries. As raw materials, biomass wastes have attractive potentials for large-scale industries and community-level enterprises. Biomass takes the form of residual stalks, straw, leaves, roots, husk, nut or seed shells, waste wood and animal husbandry waste. Widely available, renewable and virtually free, waste biomass is an important resource. The use of locally available biomass as fuel may help in stoppage of burning of crop residues in the field. Moreover, this will help in earning carbon credits. Biomass pellets are generally a superior fuel when compared to their raw feedstock. Not only are the pellets more energy dense, they are also easier to handle and use in automated feed systems. These advantages, when combined with the sustainable and ecologically sound properties of the fuel, make it very attractive for use.

Status of biomass energy :

Biomass materials are used since millennia for meeting myriad human needs including energy. Main sources of biomass energy are trees, crops and animal waste. Until the middle of 19th century, biomass dominated the global energy supply with a seventy per cent share (Grubler and Nakicenovic, 1988). Among the biomass energy sources, wood fuels are the most prominent. With rapid increase in fossil fuel use, the share of biomass in total energy declined steadily through substitution by coal in the nineteenth century and later by refined oil and gas during the twentieth century. Despite its declining share in energy, global consumption of wood energy has continued to grow. During 1974 to 1994, global wood consumption for energy grew annually by over 2 per cent rate. Presently, the biomass sources contribute 14 per cent of global energy and 38 per cent of energy in developing countries (Woods and Hall, 1994).

Biomass energy in India: Status :

Biomass contributes over a third of primary energy in India. Biomass fuels are predominantly used in rural households for cooking and water heating, as well as by traditional and artisan industries. Biomass delivers most energy for the domestic use (rural - 90% and urban - 40%) in India (NCAER, 1992). Wood fuels contribute 56 per cent of total biomass energy (Sinha *et al.*, 1994). Consumption of wood has grown annually at 2 per cent rate over past two decades (FAO, 1981; FAO, 1986; FAO, 1996).

Ministry of New and Renewable Energy (MNRE, 2009), Govt. of India estimated that about 500 Mt of crop residue is generated every year (Table 1). There is a large variability in crop residues generation and their use depending on the cropping intensity, productivity and crops grown in different states of India. Residue generation was highest in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt).

Among different crops, cereals come first with 352 Mt residue generation followed by fibres (66 Mt), oilseed (29 Mt), pulses (13 Mt) and sugarcane (12 Mt). The cereal crops (rice, wheat, maize, millets) contribute 70 per cent while rice crop alone contributes 34 per cent of crop residues (Fig. 1). Wheat ranks second with 22 per cent of residues whereas fibre crops contribute 13 per cent of residues generated from all crops. Among fibres, cotton generates maximum (53 Mt) with 11 per cent of crop residues. Coconut ranks second among fibre crops with 12 Mt of residue generation. Sugarcane residues comprising tops and leaves generates 12 Mt *i.e.*, 2 per cent of crop residues in India.

Estimates of biomass consumption remain highly variable (Ravindranath and Hall, 1995; Joshi *et al.*, 1992) since most biomass is not transacted on the market. Supply-side estimates (Ravindranath and Hall, 1995) of biomass energy are reported as: fuelwood for domestic sector- 218.5 million tons (dry), crop residue- 96 million tons (estimate for 1985) and cattle dung cake- 37 million tons. A study (NSSO,1997) estimates the consumption of fuel wood in

Table 1 : Generation and surplus of crop residues in various states of India

States	Residue generation (Mt yr^{-1})	Residue surplus (Mt yr^{-1})
Andhra Pradesh	43.89	6.96
Arunachal Pradesh	0.40	0.07
Assam	11.43	2.34
Bihar	25.29	5.08
Chhattisgarh	11.25	2.12
Goa	0.57	0.14
Gujarat	28.73	8.90
Haryana	27.83	11.22
Himachal Pradesh	2.85	1.03
Jammu and Kashmir	1.59	0.28
Jharkhand	3.61	0.89
Karnataka	33.94	8.98
Kerala	9.74	5.07
Madhya Pradesh	33.18	10.22
Maharashtra	46.45	14.67
Manipur	0.90	0.11
Meghalaya	0.51	0.09
Mizoram	0.06	0.01
Nagaland	0.49	0.09
Orissa	20.07	3.68
Punjab	50.75	24.83
Rajasthan	29.32	8.52
Sikkim	0.15	0.02
Tamil Nadu	19.93	7.05
Tripura	0.04	0.02
Uttarakhand	2.86	0.63
Uttar Pradesh	59.97	13.53
West Bengal	35.93	4.29
India	501.76	140.84

Source: MNRE (2009)

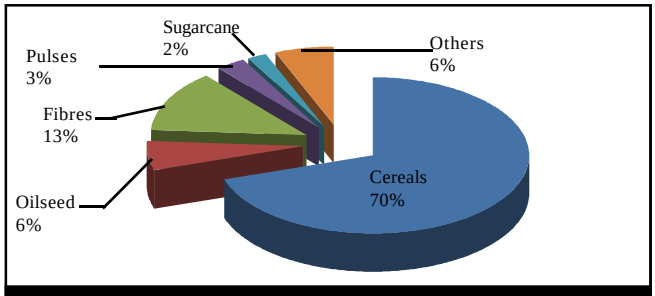

Fig. 2: Energy (kcal)

rural and urban India (Table 2).

Usage of biomass :

Traditionally crop residues have numerous competing uses such as animal feed, fodder, fuel, roof thatching, packaging and composting. Cereal residues are mainly used as cattle feed. Rice straw and husk is used as domestic fuel or in boilers for parboiling rice in states like West Bengal. The uses for various residues are different in different states. Farmers use residue either themselves or sell it to other landless households or intermediaries, who in turn sell the residues to industries. The remaining residues are left unused or burned in field. In states like Punjab and Haryana where residues are not used as cattle feed, large amount is burned in field.

SPRERI (2004) made an estimate of crop residues burnt as 71.6 Mt in selected states of country in 2001 (Table 3). The 40 per cent and 50 per cent of cotton and mustard stalks

Table 2 : Fuel wood consumption in urban and rural (cash purchase vs. home grown and collection)

States	Urban			Rural		
	Fuel consumption (in kg)			Fuel consumption (in kg)		
	Cash purchase	home grown/ other stock	% Home grown or other sources	Cash purchase	home grown/ other stock	% Home grown or other sources
Andhra Pradesh	4.8	0.1	1.2	2.2	1.1	34.5
Arunachal Pradesh	16.4	11.7	41.6	4.1	46.0	91.8
Assam	9.5	0.5	5.0	3.5	14.4	80.7
Bihar	2.4	0.3	10.4	1.7	3.3	65.9
Goa	2.4	0.1	5.1	2.7	0.6	18.4
Gujarat	1.7	0.2	10.6	0.9	4.2	82.2
Haryana	3.1	0.6	17.3	0.7	8.7	92.2
Himachal Pradesh	0.8	0.3	28.8	1.0	13.7	93.5
Jammu &Kashmir	0.7	1.3	65.3	1.1	22.6	95.2
Karnataka	6.1	0.6	9.2	2.9	7.4	72.0
Kerala	8.9	7.2	44.7	5.6	13.7	71.0
Madhya Pradesh	5.4	0.2	3.9	1.9	3.0	61.5
Maharashtra	61.7	0.2	8.5	1.8	2.6	58.8
Manipur	13.6	2.1	13.2	9.8	15.6	61.4
Meghalaya	7.3	0.3	4.4	2.8	20.5	88.0
Mizoram	1.7	7.6	82.0	0.2	25.4	99.4
Nagaland	10.4	7.6	42.3	1.5	40.8	96.6
Orissa	8.9	0.3	3.0	3.9	2.3	36.3
Punjab	2.3	0.2	9.9	5.1	4.3	46.1
Rajasthan	4.2	1.7	29.4	1.5	15.3	90.9
Sikkim	0.1	0.8	93.1	1.3	35.5	96.5
Tamil Nadu	5.4	0.3	5.7	2.8	3.4	54.1
Tripura	20.1	1.7	8.0	13.2	8.8	40.0
Uttar Pradesh	4.1	1.1	26.6	1.3	6.2	82.6
West Bengal	10.	0.4	26.4	2.0	4.8	71.0

Source: NSSO(1997)

Table 3 : Crop residues burnt in India

Crop	Major producer states having surplus crop residues	Amount of crop residues (million tone)	Surplus crop residues (million tone)
Rice	Punjab, Haryana	18.6	15.8
Wheat	Punjab, Haryana, UP, Rajasthan, MP	67.6	15.4
Sugar cane	UP, Maharashtra, Karnataka, Tamil Nadu, AP, Gujarat	26.9	21.6
Ground Nut	Gujarat, Tamil Nadu, Karnataka, AP	15.4	3.3
Mustard	Rajasthan, UP, MP, Haryana, Gujarat	9.4	4.5
Cotton	Gujarat, Maharashtra, Haryana, Punjab, Rajasthan, Karnataka	29.4	11.8
		Total surplus	71.6 Mt

Percentage given in parenthesis (SPRERI, 2004)

are available as surplus out of their total stalk generation of 29.4 and 9.4 Mt, respectively.

Among the crop residues, cotton stalk represents about 4 per cent of the total amount of residues.

Effects of residue burning in field :

Loss of nutrient :

Almost entire amount of C, 80 per cent of N, 25 per cent of P, 50 per cent of S and 20 per cent of K present in straw are lost due to burning and pollute the atmosphere. If the crop residues are incorporated or retained, the soil will be enriched, particularly with organic carbon and N.

Air pollution due to trace gas and aerosol emission :

Burning of agricultural residues, represent a significant source of chemically and radiatively important trace gases and aerosols such as CH_4, CO, N_2O, NOX and other hydrocarbons to the atmosphere affecting the atmospheric composition. It also emits large amount of particulates that are composed of wide variety of organic and inorganic species. One ton straw on burning releases 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2.

Health effects :

Studies, from many countries have indicated that biomass fuel leads to very high levels of indoor air pollution (Smith,1993) and there is growing concern about the health effects of this exposure, particularly among women and children. Health problems associated with indoor air pollution include acute lower respiratory infection (ALRI) among children, currently the leading cause of mortality in children under 5 years (Mc Cracken and Smith, 1997; Bruce *et al.*, 1998). Consequently, women and children are exposed to high levels of indoor air pollution every year (Bruce *et al.*, 2000). Exposure from biomass smoke is estimated to cause a global death toll of 2.5 million every year equivalent to 4-5 per cent of total global deaths (Paikh *et al.*, 2001; Mishra, 2003; Joshi, 2006; Peter and Vennila, 2007; WHO, 2008). Thus, indoor air pollution due to the use of solid fuels for cooking in developing countries is a major factor in increasing the environmental burden of disease.

Interventions for appropriate use of biomass for reducing indoor air pollution :

Briquetting and pelletizing is an appropriate technology for harnessing renewable fuel-energy from this huge stock of biomass. Biomass pellets are generally a superior fuel when compared to their raw feedstock. Not only are the pellets more energy dense, they are also easier to handle and use in automated feed systems. These advantages, when combined with the sustainable and ecologically sound properties of the fuel, make it very attractive for use. The standard shape of a fuel pellet is cylindrical, with a diameter of 6 to 8 millimetres and a length of no more than 38 millimetres. A high-quality pellet is dry, hard, and durable, with low amounts of ash remaining after combustion. Forest and sawmill residues, agricultural crop residues, and energy crops can be densified into pellets.

Conclusion :

Most biomass energy in India is derived from owned sources like farm trees or cattle, or is collected by households from common property lands. The biomass energy consumption is primarily limited to meet cooking needs of households and traditional industries and services in rural areas. The incomplete combustion of biomass in traditional stoves releases pollutants like carbon monoxide, methane, nitrogen oxides, benzene, formaldehyde, benzo(a)pyrene, aromatics and respirable particulate matter. These pollutants cause considerable damage to health, especially of women and children who are exposed to indoor pollution for long duration (Smith, 1993). Conversion of biomass into pellets and burning it in improved pellet stoves can help to overcome the problem of inefficient combustion besides mitigating the health problems associated with smoke pollution. Improving access to this affordable, clean, smoke-free energy is critical for reducing women's drudgery and improving the quality of life in rural areas. This will ultimately result in maintaining sustainable health of the environment and the economy.

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