ENVIRONMENTAL AND HEALTH ASPECTS OF BIOMASS ENERGY SYSTEMS*

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In a recent study (1) undertaken to ensure the early incorporation of environmental considerations in decisions concerning biomass-to-energy systems, a number of issues emerged indicating the need for early attention to environmental, socio-economic and health concerns. Both production of biomass as well as conversion can lead to environmental impact, and although most impacts will be site-specific, some generic effects can be identified. The most important potential impacts arise first, from the need for large-scale commitment of resources for production, and second, from uncontrolled widespread small-scale utilization.

Because biomass-related impacts cover a very broad spectrum of materials, processes, end products, and effects, the discussion presented here, except for an overview of generic effects and comment on production impacts, will be directed primarily to those resulting from residential wood combustion.

Table I summarizes the potential negative impacts associated with biomass energy systems. Small scale refers to on-farm, residential or small commercial facilities and large-scale implies industrial size. It is assumed that implementation of completely effective environmental control for either biomass production and harvesting or small-scale conversion will be difficult to attain whereas industrial installations will be subject to existing or future regulation on air, water, and solid waste emissions. This accounts in some cases for a greater severity of impacts projected for small-scale application compared to industrial-scale deployment of the same technology. A note of caution is essential in interpreting the data in Table I. Because biomass systems are not yet well defined and because many of the issues are complex and far-reaching, assessment of the severity of environmental impact at this time must be considered only as an indicator of potential for negative effect and definitely not as a prediction of unavoidable impact. This is especially applicable to the as-yet-unripe technologies involving energy cultivation, such as silviculture, agriculture, and mariculture (marine farming).

Potential impacts of biomass production, which can be summarized in terms of:

- Land use (and abuse)
- Water use (and abuse)
- Erosion and sedimentation
- Agricultural and forest runoff
- and Disturbance of ecosystems,

can be attributed directly to the necessary properties of an energy farm:

- Intensive species management
- Fast growing and regenerative species (monocultural)
- Short rotation time
- Weed and pest control
- Large land tracts
- and Use of presently underutilized land.

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Table I: SUMMARY OF POTENTIAL IMPACTS OF BIOMASS ENERGY SYSTEMS

Conversion impact categories	Wood combustion small-scale	Wood combustion large-scale[c]	Agriculture residue combustion	Gasification small-scale	Gasification large-scale[c]	Liquefaction[c]	Pyrolysis[c]	Anaerobic digestion small-scale	Anaerobic digestion large-scale[c]	Fermentation herbaceous small-scale	Fermentation herbaceous large-scale[c]	Fermentation lignocellulosic large-scale[c]
Solid waste disposal	VL	L	VL	L	M	M	L	VL	M	VL	M	M
Air quality	VH	M	H[e]	L	L	L	L	VL	L	VL	L	M
Water quality	VL	VL	VL	M	M	M	L	VL	L	VL	L	M
Institutional and social	M	M	VL	L	I	L	L	M	L	M	VH	L

Production and harvest impact categories	Wood from residues marginal forests	Silvicultural plantations	Agricultural residues	Agricultural plantations	Manure	Freshwater biomass	Marine biomass[b]
Land use	VL	VH	VL	VH	VL	H	H[d]
Soils	M	H	VH	H	VL	-	-
Air quality	M	M	H	H	VL	VL	U
Water quality	M	M	H	H	VL	M	H
Institutional and social	H	VH	L	VH	L	M	VH
Wildlife and ecosystems	M	H	L	H	VL	M	H

[a] Impact severity index
VH - Very high L - Low
H - High VL - Very low
M - Moderate U - Uncertain

[b] Estimates of potential for marine systems development are widely divergent. Impacts in every category could vary from low to very high, depending on the eventual extent of deployment.

[c] Assumes larger scale facilities are subject to environmental control technology

[d] Refers to use of ocean surface rather than land

[e] Assumes that NO_x scrubbers are not yet commercially available in the U.S.

Source: Reference (1)

Because biomass energy production systems are projected as operating on a very large scale, the projected environmental impacts tend to be an exaggeration of well-defined effects which are now controlled or mitigated in existing production and harvest schemes. For example, land use impacts of energy production arise from the need for a large commitment of land (it requires 38 million acres to produce one quad of energy). Land is unavailable except either in competition with food, fiber, or livestock production, or by using underutilized land. Land is only underutilized when it is of low quality and unsuitable for cultivation because of problems such as wetness, dryness, or high erosion potential. Potential environmental impacts of intensive monoculture cultivation of low quality, marginal, or uncultivated lands have been well documented (1). In addition to possible water and soil nutrient depletion, and air and water pollution, conversion of such areas to biomass plantations could result in destruction of the last remnants of once-extensive wildlife habitats.

In order to effect the release of the energy in biomass materials, they must be converted either directly, by combustion, or indirectly, by thermochemical or biochemical conversion. This involves a wide variety of technologies, many different processes, and various-size operations. Of the resulting array of biomass-to-energy options, one of the most familiar and readily available is residential wood combustion. Unfortunately, few definitive environmental impact data exist for this use. Because wood burning is relatively free of some of the most serious environmental problems associated with coal combustion such as solid waste disposal and sulfur dioxide emission, and because environmental control is difficult to implement at the home-owner level, little attention has been focused on environmental management of this biomass application. However, home wood burning, which is becoming increasingly more popular and widespread, produces air emissions which, if uncontrolled, can pose a threat not only to the environment but also to human health. The important thermal decomposition products of wood are smoke (a mixture of solid particles and condensed liquid particulates), volatile hydrocarbons, and carbon monoxide. Significantly, even when wood burning produces low concentrations of smoke, large quantities of carbon monoxide may be produced (2). Additionally, the conditions that promote abundant emission of both smoke and carbon monoxide are exactly those prevalent in the conventional residential wood stove or fireplace (1).

Unfortunately, attempts to estimate the air quality impacts of small-scale residential combustion are hindered by the lack of standard techniques such as exist for assessing the emissions associated with large centralized sources. The latter commonly employ sophisticated emission abatement devices, uniform fuels, and carefully designed, operated, and maintained combustion devices. None of these assumptions apply to the residential wood stove. Nonetheless, the rapid pace with which wood stoves are replacing more conventional heating sources and the consequent potential for environmental impact, demands an evaluation.

Available predictive techniques were utilized to predict ground-level concentrations of pollutants from wood combustion devices. These techniques (3) assume Gaussian distributions of pollutants, and are most applicable in flat to gently rolling terrain. Concentrations can be calculated for a variety of pollutant emission rates, wind speeds, and wind directions. Using this typical Gaussian dispersion approach, the values in Tables II and III were obtained. The time and distance dependence were determined for groundlevel concentrations of emissions from one wood combustion device burning 3 kg of wood per hour under the following typical meteorological conditions:

wind speed	2m/sec
effective emission height	10 m
atmospheric stability	stable, class E.

Table II - Maximum One-hour Ground Level Concentrations Of Emissions From One Wood-burning Device ($\mu g/m^3$)

Downwind Distance (m)	Stove (oak) Particulates[a]	Stove (oak) Hydrocarbons[d]	CO[e]	Stove (pine) Particulates[b]	Fireplace Particulates[c]
10	-	-	-	-	-
25	1.5	1 - 32	114	8.8	13.2
50	4.6	3 - 98	354	27.2	40.7
75	4.2	3 - 87	320	24.6	36.8
100	3.3	2 - 70	254	19.5	29.2
150	2.1	1 - 45	161	12.4	18.6
200	1.5	1 - 31	111	8.5	12.8
250	1.1	0.7 - 23	82	6.3	9.4
300	0.8	0.5 - 17	62	4.8	7.2

Table III - Peak Concentrations ($\mu g/m^3$)

Time[f] (hrs)					
1	4.7	3 - 99	356	27.4	41.1
3	3.2	2 - 67	242	18.6	28.0
24	1.5	1 - 32	116	8.9	13.3

Table IV - Short-term Worst-case Estimates From A Study Area[g] ($\mu g/m^3$)

10	-	-	-	-	-
25	53	31 - 1071	4017	309	463
50	52	30 - 1070	3991	307	459
100	51	30 - 1050	3939	303	453
150	51	30 - 1040	3900	300	445
200	50	29 - 1029	3809	293	439
250	49	29 - 1009	3718	286	428
300	48	28 - 988	3666	282	422

a) ref. (5). Emissions: 1.7 g/kg wood
b) ref. (5). Emissions: 10.0 g/kg wood
c) ref. (6). Emissions: 15.0 g/kg wood
d) ref. (7). Emissions: range 1 g/kg to 35 g/kg wood
e) ref. (8). Emissions: 130 g/kg wood
f) Time scaling factors from ref. (9)
g) Study area:

Size	1/2km x 1/2km
Housing density	4 units/acre = 247 dwellings
Wood use	3 kg/hr/house
Emissions rates same as in Table II	

In the Clean Air Act Amendments of 1977 (PL 95-95), the EPA defined that amount of adverse effect on air quality allowed in the prevention of significant deterioration (PSD) regulations. Presently, only large facilities such as industrial sources and power plants are reviewed for PSD compliance. However, the allowable deterioration represents reasonable levels of air quality degradation deemed acceptable. PSD increments for particulates (none exist for carbon monoxide or hydrocarbons) are given for Class I & II areas (4). For presently pristine (Class I) areas increments are 10 $\mu g/m^3$ maximum for a 24 hour period with an overall mean maximum of 5 $\mu g/m^3$; for typical (Class II) areas, particulate concentrations are limited to a 24 hour maximum increment of 37 $\mu g/m^3$ and a mean of 19 $\mu g/m^3$. Clearly, values in Table II show that of several woodburning stoves located within 100 meters of each other would exceed allowable increased in pristing areas and would consume much of the allowable increases in typical areas.

Were a community of houses to convert to wood heat, under adverse meteorological conditions (inversion with a 15 meter stable layer), the air quality impact would be far more severe, as indicated in Table IV. The study area in Table IV represents a typical small community, and the dispersion conditions are representative of small Appalachian region. The assumed adverse conditions represent a realistic worst case situation that could be expected to occur nightly in some locations in the southeastern U.S. and in New England occasionally lasting for up to 24 hours. If all 247 houses in the community heat with wood for four months the total particulate emissions from a 1000 MWe coal-fired power plant serving the needs of approximately 500,000 people using a state-of-the-art particulate removal system (99.5% efficient) would emit approximately 13 tons of particulate during the same time period (10). In addition, although little is known about the potential health effects of long-term exposure to wood combustion particulates, many of the identified hydrocarbons are known carcinogens (1). Additionally, preliminary studies indicate the potential for adsorption of polycyclec aromatic hydrocarbons onto the surface of respirable-size wood ash particles (11).

The level of carbon monoxide downwind of the small community is within the current ambient 8 hour maximum standard of 10,000 $\mu g/m^3$ (4). However, the 4,000 $\mu g/m^3$ should perhaps not be considered inconsequential. Animal studies indicate that exposure to low levels of carbon monoxide for periods as short as four hours converts the myocardium from aerodic to anaerobic metabolism leading to ultra-structural heart damage (12).

Biomass-to-energy systems, by utilizing a revewable resource, can make an important contribution to our overall energy needs. However, insurance of environmental acceptability will require close attention to the possible impacts of rapid, impulsive, and uncontrolled implementation. Our habit has been to accomodate dispersed, small-scale environmental alterations and to consider local effects as insignificant relative to the large centralized source. Implicit in this accomodation is the doctrine that environmental dilution is equivalent to environmental dissipation. But because a renewable technology is a long-term technology, an in-depth evaluation will require knowledge about low-level, long-term effects. Unfortunately, this is an area that we know little about. Thus, until this information is available, it may be difficult to assess long-term effects of the large number of relatively small, dispersed disturbances that can arise from this broad-based technology.

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