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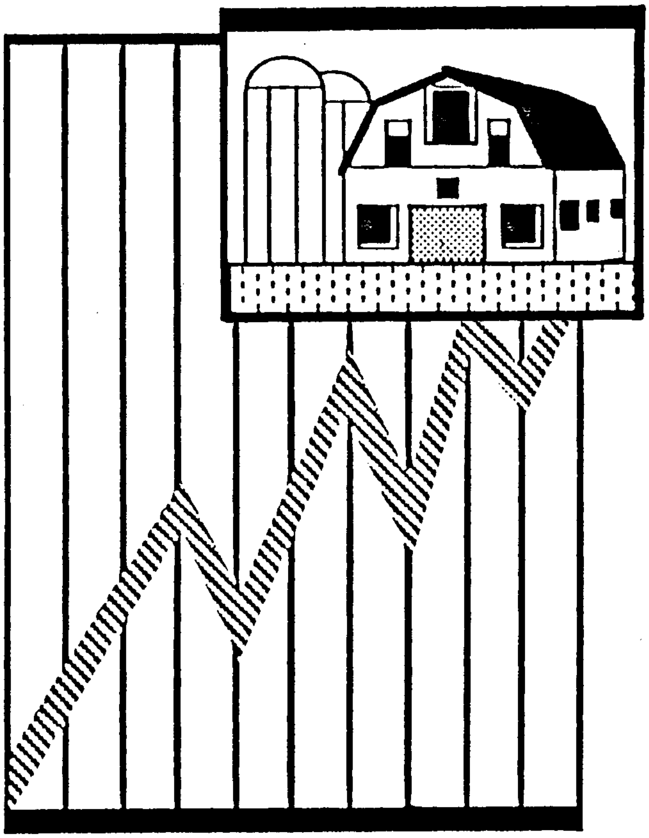

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by

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Energy in Economic Perspective

The political economy of farm biomass (grown organic matter) for energy is primarily related to the supply and demand of fossil fuels, the price of corn, woodchips, livestock waste, and other potential biomass fuel sources for non-energy uses (e.g., livestock feed, pulp, compost) and the nature of government agricultural and energy policy. Political economy refers to a broader notion of resource allocation than "free" markets including constitutional rules, property rights, and various forms of market correction or adjustment. Calls for greater use of farm products for energy, e.g., ethanol fuel from corn grain, are usually loudest when corn prices are lowest. The interest dissipates when higher grain prices (either market based or government supported) resume. This makes it difficult to sustain grain supplies for the relatively capital-intensive farm level biomass energy conversion alternatives such as alcohol stills. Thus, this paper will focus on assessing the factors influencing the economic feasibility of non-grain based farm biomass energy options, present some preliminary evidence of biomass biological and economic potential at the farm level in Ohio, and develop a plan for further research.

Prior to 1800, world population was controlled primarily by famine and pestilence. Man was generally dependent on draft animals and wood for tillage, transportation, and energy. Since 1800 world population and energy use have increased dramatically. Webb correlates this development with the exploration and closing of the frontier -- "an inherently vast body of wealth without proprietors -- they swarmed out like bees to suck up the nectar of wealth, much of which they brought back to the mother hive."[1] The discovery of fossil fuels and modern technology greatly facilitated development of the frontier. Increased energy efficiency, ease of attainment, and a disregard for its finiteness made fossil fuels cheap energy sources that rapidly replaced previous biomass sources. The oil embargo in 1973, subsequent activities of the OPEC oil cartel, and military conflict in the Middle East resulted in rapid oil price increases in the late 1970s. This was commonly referred to as "the energy crisis", even though fuel wood is the primary energy concern for the developing world.

The weakening of the oil cartel, recession, energy conservation, etc. in the early 1980s led to a decline of oil prices which in turn has resulted in cutbacks of U.S. exploration and production, increased consumption and dependence on OPEC oil, and reduced incentives for development of renewable energy alternatives. For example, the U.S. imported 27 percent of the petroleum and refined products it needed in January 1985. This was down from 35 percent before the 1973 Arab oil embargo and down from 43 percent before the 1978 Iranian revolution that disrupted oil supplies. By January 1986 oil imports to the

U.S. were back up to 34 percent of total consumption with the OPEC cartel share increasing from 31 to 41 percent of all oil imports in the preceding 12 months. From January 1986 to January 1989, gross oil imports increased from 5.6 to 8.0 bbl/day [2].

The traditional fossil fuel energy sources are non-renewable, exhaustible, or stock resources that do not increase in physical quantity over time. Some, such as coal, are not significantly affected by natural deterioration. Others such as oil and gas in cases of seepage and blow off can be significantly affected by natural deterioration. However, Ciriacy-Wantrup argues that use of concepts such as exhaustible and inexhaustible have meaning only in an economic context. Long before a given resource is physically used up or even appreciably diminished, it may be exhausted in the sense that further utilization is discontinued (due to it relative price or cost) in spite of continuing human wants. Alternatively, a resource may be inexhaustible in the sense that utilization continues indefinitely, even though it is relatively limited in physical quantity compared to other sources [3].

In addition to supply limitations, there are some fundamental questions raised relative to appropriate pricing of energy resources. Margolis suggests some of the reasons private market prices may not reflect full social benefits or costs with the following:[4]

> "... there are many cases where exchange occurs without money passing hands; where exchanges occur but they are not freely entered into; where exchanges are so constrained by institutional rules that it would be dubious to infer that the terms were satisfactory; and where imperfections in the conditions of exchange

would lead us to conclude that the price ratios do not reflect appropriate social judgments about values. Each of these cases gives rise to deficiencies in the use of existing price data as the basis for evaluation of inputs or outputs."

Some have argued that in contrast to recent cartel impacts, a combination of political expediency and the private market's inability to price external effects and non-renewable resources has generally created artificially cheap energy sources and minimal incentives for conservation in many countries. Commoner holds that this underpricing has led to the substitution of high energy, capital intensive structures for labor [5]. Free market proponents argue that price alone should determine the extent and definition of conservation. Thus, energy conservation is a rational response to higher energy costs relative to other prices, and swift deregulation of energy markets is the way to realize energy conservation.

Some of those calling for higher taxes on energy, particularly gasoline, may agree that deregulation is a necessary condition, but argue that it is not a sufficient condition for optimal energy use. The failure of the "free" market to reflect full social costs from such externalities as oil spills, military escort costs, acid rain and the greenhouse effect from fossil fuel combustion, balance of payment deficits, and the potential disruptive economic and national security costs of an oil embargo are frequently cited reasons for higher gasoline and other energy taxes or prices. For example, Dovring argues that the Persian Gulf is hardly a place that the U.S. should trust with half or more of its transportation fuel. Supplies from that area carry heavy overheads in military and political costs which if factored into the price of petroleum would make it far less attractive [6]. Tyner and Wright argue for the addition of a premium to the price of oil for the risk of the disruption of oil supplies [7].

Boulding argues that the "spaceship" earth requires some revised economic principles from conventional economics, i.e., in the closed economy, throughput (production and consumption) is not a measure of success but rather something to be minimized [8]. Georgescue-Roegen emphasizes that all natural resources are eventually consumed. He views economics, like biology, to be evolving towards a greater consideration of the environment [9]. Randall argues that economists are simply rediscovering the first and second laws of thermodynamics. The first law (the principle of conservation of energy-matter) explodes the myths of waste-free production and total consumption. The second (entropy law) states that the entropy of a closed system continuously increases [10]. In other words, the order of such a system turns steadily to disorder. The first law suggests that waste disposal is an integral part of production and consumption processes in energy as well as other areas. The second law supports the increased use of flow energy resources (e.g., biomass) and the development of more entropy-efficient technologies.

As we look to future alternative energy sources, certain implications are clear. First, we must not limit our search for alternative sources to present use technologies. New sources as well as more entropy -- efficient sources and uses must be explored in part because the direct costs of extraction of current sources will be substantially higher in the future. Secondly, as we continue to expand use against a limited environment, current market prices to develop and supply energy may not be a sufficient criterion to judge acceptability. Technological and political externalities will increasingly need to be considered as will social time preferences versus market interest rates for depletion of some finite resources.

Agricultural Biomass for Energy

Conversion of biomass for energy is not a new topic. Until the late 1800s all energy came from biomass sources through the burning of wood or other materials [11]. During the depression and before and after the world wars, research on biomass conversion developed whenever the supply of coal or oil became threatened [12]. At present, limited research is focusing on alternative conversion processes and biomass sources for entropy efficient transformation of biomass into energy Several conversion technologies using a variety of primary biomass sources to produce a wide array of products are illustrated in Figure 1. Although research on technical conversion processes is ongoing [13], the lack of financial feasibility of many processes in the past has limited widespread adoption. As noted earlier, current fossil energy prices are not the appropriate yardstick for determining eventual feasibility, since economic feasibility may change as relative energy prices change and as externalities are internalized or included in the price of fossil fuels.

Sustainable biomass conversion processes have certain distinct advantages over fossil fuel processes: they are relatively efficient in capturing energy, less polluting (e.g. acid rain), neutral on global warming, and they produce important by-products. Moreover, they utilize renewable resources society often regards as wastes. Two general bio-conversion processes exist, microbial and thermochemical. Microbial processes convert biomass to fuels or chemical feedstocks by microbial or enzymatic degradation. Thermochemical processes utilize heat, pressure, or chemicals to convert biomass to fuels [11].

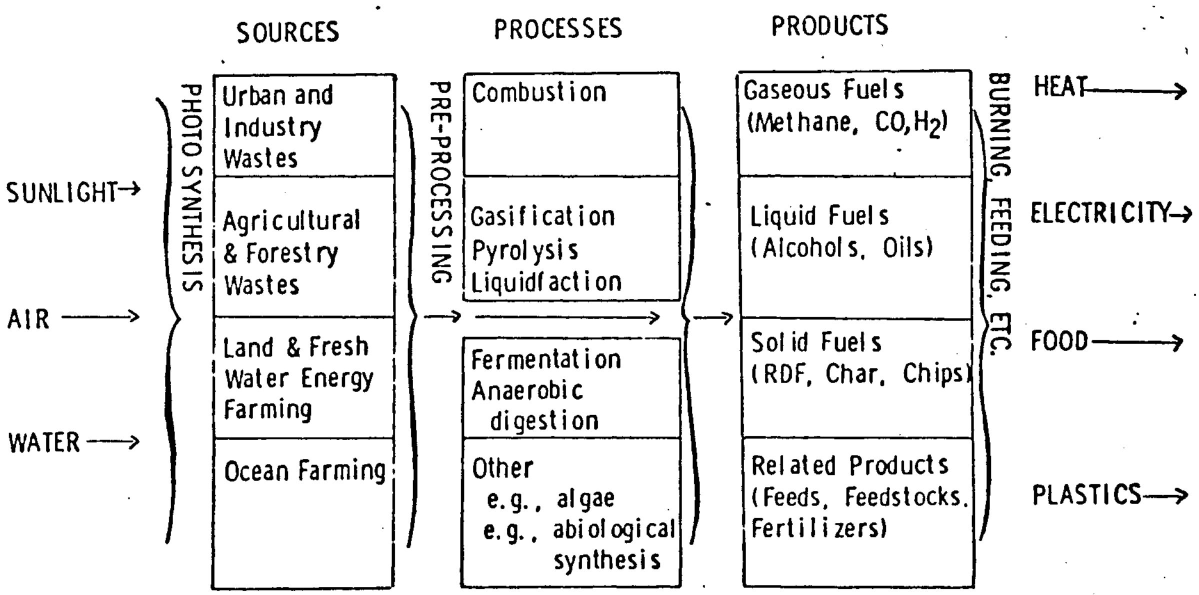

Figure 1. Biomass Sources, Processes, and Products.

Microbial conversion processes include anaerobic digestion, fermentation, enzymatic decomposition, and biophotolysis. Anaerobic digestion breaks down cellulosic materials, i.e., wastes, residues, and crops, through bacterial digestion to produce methane or synthetic natural gas. The fermentation of sugars, derived from the breakdown of cellulosic materials, produces liquid fuels such as ethanol or methanol. Degradation of cellulosic materials by enzymatic hydrolysis or decomposition also produces liquid fuels. Biophotolysis, although not strictly microbial, is a new technology attempting to capture energy from hydrogen by separating hydrogen from the photosynthetic process in blue-green algae [14].

Examples of thermochemical conversion processes are complete combustion, pyrolysis, gasification, liquifaction, resource recovery, and chemical treatment. Complete combustion is the age-old process of direct burning for heat or steam. Pyrolysis refers to destructive distillation of wood or cellulosic material without oxygen to form methane or oils. Gasification, often confused with pyrolysis, also decomposes cellulosic material in a similar fashion as pyrolysis but under aerobic conditions to produce gaseous fuels or oils. High temperatures and pressures liquify biomass forming liquid fuels in the liquification process. Resource recovery processes compress and/or pelletize solid waste to form refuse-derived fuels (RDF), used as supplementary fuels. Chemical treatment of biomass by such agents as solvents, catalysts, or carbon monoxide increase conversion yields of cellulosic materials to different forms of energy [14].

Utilization of the various conversion technologies depends on technical feasibility, costs, economies of scale, and desired end-products. Anaerobic digestion, for example, is the most widely used and inexpensive process, but primarily employed in small-scale operations for removal of residues and wastes. Pyrolysis and fermentation are more expensive processes and are applicable primarily to large-scale operations [15]. Studies to date have not provided in-depth economic analyses of conversion processes. Neither has there been adequate research examining combinations of processes and biomass sources that are most appropriate and feasible. This is understandable given the limited funding and attention such research has received in the past.

Biomass for energy can come from residues or direct production. Residues from U.S. feedlot and crop wastes were estimated by Hammond [16] to be almost two times the amount of energy used by agriculture. Burwell estimates that if annual U.S. biomass production for food, lumber, paper, and fiber were used exclusively for energy, it would provide 25 percent of current energy requirements [17]. A study for the Office of Technology Assessment, U.S. Congress estimates available crop residues of 70 to 86 million tons per year and energy crop potential of 6.8 to 10.3 billion gallons of ethanol per year [18]. Direct production of crops for energy is more controversial due to greater competition with food production.

The use of residues or crops for energy involves some important considerations. First, the energy input needed to gather the residue or produce the crop, transport it, and process it may exceed the energy output. Second, use of residues or crops may reduce the fertility or increase the erosion of agricultural land and may reduce food production. Use of biomass for energy may be preferred if it is complementary rather than competitive with food production and environmental pollution control. The key to coordinating biomass production with food production may involve utilizing crop residues, marginal land, rotations, and biomass conversion by-products for fertilizer and feed.

An earlier effort by Hitzhusen, Rask, and Gowen summarized the state of research on biomass for energy and several implications evolved from the studies summarized [14]. First, the conversion of biomass sources to energy lacks comprehensive economic analysis and, second, what analysis has been done shows most biomass to be non-competitive at least at present fossil fuel prices. Municipal wastes appear to be a promising source, but total energy potential from garbage and sludge is limited. Crop residues such as corn stover may already be economically feasible under certain conditions such as combustion with high sulfur coal in steam-electric plants [19]. Silviculture or forestry production of biomass has great potential but will receive strong competition from the wood products industry. The feasibility of converting areas in the Northeastern U.S. to direct burning of wood is under study. Already many lumber companies are converting to direct burning to become self-sufficient. However, direct burning may be a less efficient means for capturing energy than other thermochemical or biological conversion processes.

Crop production, besides silviculture, was found to hold the greatest long-run potential for providing new energy sources from biomass. For example, the costs for converting most crops to fuel ranged between $1 to $2 per gallon of liquid fuel, indicating that crops for energy were not competitive with U.S. liquid fuels [14]. Production of sugar cane, corn, and sweet sorghum for fuel were three areas of research that had received significant attention [20, 21, 22]. Sweet sorghum, for instance, provided various types of fuels as well as several useful by-products. A comparison between corn and sweet sorghum by Battelle Laboratories [22] indicated the latter may have cost as well as by-product advantages. Since sales from by-products reduce overall costs of conversion they may be, in some cases, the key factor determining the use of biomass for energy.

There are also negative aspects to biomass use. Arguments against crop production for energy or the use of residues for energy, stress soil and fertility loss and the removal of potential food and livestock feed. However, some crop by-products may replace part of the fertilizer and feed removed, as well as provide other important chemical and fiber products. In the long-run, there may be distinct advantages in utilizing certain crops for energy if the by-products can decrease dependence on products derived from fossil fuels. Thus, Lipinsky has argued that biomass for energy must be viewed as part of an integrated system [23].

Some Preliminary Evidence in Ohio

An inventory of Ohio biomass potential by county was completed by Hitzhusen et al. in 1982 [24]. The results were intended to present a relatively conservative set of first approximations of annual wood energy, crop residue, livestock manure, and solid waste energy potential in each of Ohio's counties. With the exception of methane from livestock manure, all estimates reflect sustainable biological not economic potential. Sustainable or usable biological potential is that amount remaining after competing uses (e.g., livestock bedding, pulpwood) and soil protection (e.g., cover and organic matter) have been netted out. The following tentative conclusions were drawn from the inventory:

1. Wood biomass (159.4 x 10^{12} BTU/yr) constitutes the largest potential biomass energy source for Ohio, far exceeding other biomass sources and providing about *54% of the annual total of biomass for energy potential.* This is over double the amount of crop residue or municipal solid waste. In particular, the Southeastern, South Central, East Central, and Northeastern regions hold the substantial fraction of the total, with 24.7, 37.0, 33.7, and 38.6 x 10^{12} BTU's respectively. These areas, as expected, correspond to the major timber producing regions of Ohio. In summary, wood looks quite promising as a future energy source.

2. Crop residues, on the other hand, could provide about 64.3 trillion BTU's of energy for Ohio, or *21.6% of Ohio's total biomass energy*. Only the Northeastern, Northwestern, and Southwestern regions have large concentrations of crop residues with these areas having 10%, 67%, and 22% of the total crop residue potential, respectively. Such distinct regionality of the resource corresponds to Ohio's major agricultural producing areas. Crop residues could provide supplemental energy or chemical feedstocks [16].

3. Municipal solid wastes are more widely dispersed throughout the state and could possibly provide 69.0 trillion BTU's or *24.0% of the total Ohio biomass energy*. The major Municipal Solid Waste potential is found in the Northeastern and Southwestern regions, with 43.9% and 33.1% of the MSW potential, respectively. These concentrations correspond to the major population centers of Ohio. These concentrations suggest the feasibility of refuse burning plants in metropolitan areas [14].

4. Animal wastes for methane production show extremely limited potential, representing only 0.4% of the total biomass energy for Ohio. It would appear such a limited resource would only be feasible for small-scale gasification units that are located on farms or in rural communities near to the resources.

To put Ohio biomass potential in perspective, Table 1 presents a comparison of 1979 Ohio energy consumption for conventional categories and the annual sustainable yield of each of the biomass categories surveyed. The total biomass potential is 10 times nuclear and hydro production, but less than one-third of the next to the smallest conventional category, natural gas.

Table 1. A Comparison of Total Energy Consumption in Ohio for 1979 and Ohio's Biomass Energy Potential (10^{12} x BTU's per annum).

Use/Potential	Amount
Energy Use[a]	
Coal	1,697.3
Natural Gas	975.7
Petroleum	1,322.9
Nuclear and Hydro	29.8
Total Consumption	4,025.7
Biomass Energy Potential[b]	
Sustainable Wood	159.4
Municipal Solid Waste	69.0
Usable Crop Residues	64.3
Livestock Wastes	0.4
Total Biomass	293.1

[a]Source: Table 5 in Ohio DOE, 1979 Energy Status Report.
[b]Source: Table 9, totals for each category [24].

Only two of the biomass inventory categories, usable crop residues and livestock wastes can be exclusively tapped to enhance farm income potential and they make up about 22 percent of total biomass potential in Ohio. Wood biomass makes up 54 percent of total potential, but only 14 percent of Ohio's forestland is owned by farmers. However, since corporations own less Ohio forestland than farmers (12.3 percent of total), there may be opportunity for farmers to lease forestland for energy production from other private owners if it becomes economically viable.

Preliminary evidence from research by Abdallah and Hitzhusen [19] suggests that crop residues may have economic potential for co-combustion with high sulfur coal at about one-third of Ohio's coal-fired steam-electric plants. Related research by Gowen and Hitzhusen [25] shows that whole tree chipping for gasification from woodlots above 20 acres is economically competitive with current natural gas and coal prices. White and Forster suggest that livestock waste in confinement facilities of at least 200 beef animals or equivalent animal/poultry units has very limited economic potential for methane or other energy production [26].

It is difficult to estimate the potential for farm income enhancement from the foregoing research results. First, the research on corn stover determined economic feasibility of co-combustion of stover and high sulfur coal by summing power plant conversion storage, harvest, and transport costs. In addition, it assumed that the minimum price the farmer would accept for his surplus stover (in excess of erosion control and livestock bedding needs) would be equal to its nutrient (N P & K) value. No analysis of farmer's actual willingness to sell was done. Secondly, the analysis of chipping of forest stands for gasification did include secondary data on average stumpage prices or willingness to sell for chipping by woodland owners. However, no data were available or gathered on the net income from woodlots under current uses, particularly those on farms. Finally, although there appear to be no examples in Ohio of methane generation from livestock manure, compost from manure and poultry manure in ruminant livestock rations are becoming more common.

Further Research Plan

The previous sections surveying research on agricultural biomass for energy pointed out the limited amount of economic analysis which has been done. Furthermore, much research which passes for "economic" analysis is oblivious to opportunity cost, technological externalities, and elasticity concepts. Costs are frequently generated from engineering data and future revenues based on current market prices. These "costs" generally do not represent full opportunity costs of all factors of production such as the value of the farmer's time in crop residue collection during the fall harvest season. These "costs" may also omit major technological externalities (just as do most fossil fuel analyses) such as soil and nutrient loss from complete removal of crop residue. "Revenues" may also be overstated, particularly in those areas where a relatively inelastic demand exists for the end product(s) and where the rate of adoption is likely to increase supply sufficiently to affect market price. Estimating revenues for various petrochemical substitutes from crop residues may be an example of this problem.

Thus the first thrust of a future research agenda for assessing the farm income enhancement potential of biomass energy in Ohio is to refine and extend the previous research on two promising subsets, corn stover and forest chips. Specifically, cost and price coefficients need to be updated for both stover co-combustion with high sulfur coal and for chipping of standing forests or woodlots for gasification. In addition, some primary data collection needs to be done of farmer's willingness to sell stover for energy and on current net income from farmer and other privately owned woodlots. Finally, it must be confirmed that the full social or environmentally related costs have been included in these biomass for energy options.

The next step is to estimate a range of social values or shadow prices for coal, gasoline, and natural gas based on available evidence on subsidies, and environmental costs [7, 27, 28, 29]. For example, the full costs of strip mine reclamation based on current Ohio law as well as economic estimates of global warming impacts and aquatic and forest acid rain damage downwind from Ohio's coal burning steam-electric plants should be included in the cost and price of electricity. Since the two key non-grain based farm level biomass options (corn stover and wood chips) are substitutes for as well as complements to high sulfur coal, the initial focus on coal environmental externalities is appropriate. However, the global warming issue is less clear than stripmine reclamation costs and acid rain economic damage when assessing coal combustion for generation of electricity.

The same acid rain and global warming arguments can be added to military escort costs and other issues when evaluating the external costs of gasoline use. However, economic assessment of these impacts may be quite difficult. One alternative is to estimate the impact on the price of gasoline and coal from implementation of pending legislation or proposals for reducing federal deficits and internalizing the external costs of fossil fuel combustion [30, 31, 32]. Examples include a 50 cent per gallon tax on gasoline, a sulfur (SO_2) emission (or acid rain) tax on coal, and a carbon dioxide (CO_2) emission (or greenhouse) tax on all fossil fuels. The SO_2 and CO_2 taxes have been proposed to both reduce fossil fuel use (conservation) and to provide revenues to compensate for damage from acid rain and global warming [33].

Once these fossil fuel shadow prices have been estimated, the focus of the research could then shift to examining other possibilities for farm level biomass income enhancement. Examples might include methane from livestock manure as well as non-energy products such as livestock feed and compost. In addition, crop and forest residues may have new potential as chemical feedstocks at least in competition with petro-chemicals. In all of these examples, full social or environmental costs will be estimated. The next stage of the research would be to suggest alternative institutional mechanisms (e.g., changes in property rights, taxes, subsidies, rules) for pricing both fossil and biomass based fuels at their full social values. Finally, the research would attempt to estimate farm income enhancement potential in Ohio under alternative scenarios for fossil fuel and non-energy based biomass prices.

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