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AUTHOR(S): VIRGINIA PARSONS

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MICRO-LEVEL LAND USE IMPACTS OF BIOCONVERSION

V. Parsons
Los Alamos Scientific Laboratory
University of California
Los Alamos, New Mexico, USA

STRACT

The energy crisis has prompted research and velopment of renewable energy sources, among which are e bioconversion technologies. Crops, crop residues nure and other organic wastes are potential sources of quid, solid and gaseous fuels. These feedstocks iginate on the farm or in the forest and therefore are nd intensive. Implementation of the bioconversion chnologies will involve actions which will impact isting land use patterns. Because of differences in op type, yield per acre, existing land use conditions d agricultural practices, an aggregated national proach to the assessment of land use is not fficient. If energy policy regarding bioconversion is be successful, then it must be sensitive to cro-level information. This paper demonstrates the nd use assessment work at the Los Alamos Scientific boratory (LASL) in support of the Department of ergy's Technical Assessment of Solar Energy Program, ASE). Local Biomass potential, existing and use and tential land use impacts from bio-energy plementation for three of the fifteen counties lected for the TASE study will be presented. The thodology created for the evaluation is useful in termining the biomass potential for any community or unty, and in identifying regional differences inherent the trade-offs between existing land use and energy oduction.

TRODUCTION

There are many reasons for the energy crisis in the S., but three emerge as major contributors; increased ergy consumption, an historic dependence on foreign urces of petroleum to replace domestic natural gas, d a gap between domestic supply and demand for energy.

First, and very simply put, the U.S. consumes more ergy than it produces. The 1978 figure of total ergy consumption of 78.2 quads is almost double the '60 figure of 44.6 quads. [1] Second, as natural gas came a major energy resource, it replaced coal. tween 1945 to 1970, the consumption of natural gas re than doubled [2]. In the early 70's when domestic oduction of natural gas began to decline, an economic bstitute was foreign crude oil. A price increase from to $34 in less than ten years, and dependence on reign oil has the United States concerned about the ate of the economy and, quite obviously, national curity interest. [3]

This energy crisis has prompted research and velopment of alternatives to foreign petroleum. cluded are the agriculture sector actions to produce newable local energy form crops, agricultural -products and wastes. As with any popular emerging ergy technology, there is considerable interest in shington. The Department of Energy has initiated the chnical Assessment of Solar Energy Program (TASE) to, part, evaluate the environmental impacts of biomass. is paper is an attempt to share the methodology and me initial results of LASL's national land-use alysis of the Bioconversion Technologies.

Approaches to land intensive energy production involve trade-offs among the existing land use practices. The policy maker should be aware of the trade-offs which are unique to each of the climate regions in which bio-energy development could occur. For example, consider a national alcohol fuels program. If sufficient grain surpluses or crop residues are not available within a region to satisfy local demand for liquid fuel, then increased production must occur to provide feedstocks for the process. To achieve this, more land must be brought into production, cultivation practices must change to increase production on existing acreage, or existing use must shift to provide a suitable energy crop. A given locale may or may not have the capability to expand the land base. In addition quality of land, the flexibility of the current market, and existing land use conflicts vary from each region. This premise is the basis for examining the bio-energy potential for several locales located in distinctly different regions. Local biomass potential compared to existing energy need reveals the micro-level land use impacts which may otherwise escape attention at the aggregated national level.

The United States has fifteen large land areas with similar precipitation and freeze-free days, when mountainous, arid, and other areas with severely limited integrated biomass potential are deleted. (fig 1) [4]


Fig. 1 Study Regions

A county from each of these regions was selected to represent the area for the TASE analysis. The selection process was initated by conversations with state bio-energy experts as suggested by the DOE. [5] The local contacts provided by state contacts include a state senator, agricultural extension personnel, mayors, city planners, managers and council members. The results for Palm Beach County, Flordia; Yamhill County, Oregon and San Saba County, Texas will be presented in this peper. These three counties exhibit examples of the varying opportunities and consequences of bio-energy production.

Methodology

Land use impacts from bioconversion will, of course, occur only as facilities are implemented and harvesting/energy production actions are made. Certain assumptions about these potential actions have been made in this analysis. First, the technologies which seem to be at the commercial development stage are fermentation, anaerobic digestion, direct combustion and gasification technologies. This has been based upon a review of the literature of pilot projects, the areas of research and development which have been funded recently, existing commercially available units, and public or popular acceptance and demonstration as revealed in the popular literature. Second, the implementation will occur at the source and will be market dependent. In other words, farmers will slowly take advantage of wastes, crop surplus, crop residues and so on as energy costs increase, and examples of working facilities convince them of reasonable economic return. The technology types which are and will continue to contribute to near-term development are:

1. Anaerobic Digestion of manure with on-farm generation of electricity, or direct gas use.

2. Fermentation of starch and sugar crops to ethanol with a by-product of distillers grain.

3. Direct combustion of crop residues and other woody biomass for electricity or process steam. It is particularly advantageous to co-fire fossil fuels during peak seasons with biomass derived fuels. This will occur at the community electrical generating level, at timber or food processing industries, for on-farm crop drying and continued increase in home wood heat applications.

4. Small scale gasifiers for crop-drying, on-farm electricity generation and by-product fuels.

The following conversions of biomass to energy were used in this analysis. In all cases, these are conservative estimates.

1. Anaerobic Digestion [6]

The primary product is biogas, 60% $CH_4$, 40% $CO_2$ at 600 BTU/$f^3$. The following figures are for the combustible portion, $CH_4$, per day, per animal, based on average weight and continuous feed. Heat for the digestor has been taken into account.

| animal | yield |
|---|---|
| Dairy Cattle | 14.8 $f^3$/day |
| Beef Cattle | 15.7 |
| Chickens | .06 |
| Hogs | 2.12 |
| Sheep | 2.12 |
| Turkeys | .32 |

On farm electrical generation of biogas in an internal combustion engine (20% efficiency) is 17 $f^3$/kwh.

2. Fermentation [7]

The end product is ethanol at 80,000 BTU/Gal. Yield is given in gallons per unit and per acre based on average yield. This does not reflect energy needed for collection, transportation and distillation.

| crop | yield/Bu | yield/acre |
|---|---|---|
| corn | 2.35 gal | 214 gal |
| sorghum | 2.22 | 125 |
| sweet sorghum | N/A | 500 |
| wheat | 2.57 | 79 |
| yams | .94 | 190 |
| sugar cane | N/A | 555 |
| sugar beet | N/A | 412 |
| apples | .35 | ~~740~~ 140 |
| rye | 2.20 | 54 |
| oats | 1.02 | 57 |
| barely | 1.90 | 83 |
| rice | 1.79 | 175 |
| potatoes | .69 | 299 |
| peaches | .28 | 84 |
| plums | N/A | 21 |
| carrots | .25 | 121 |
| grapes | N/A | 90 |
| Jerus. artichokes | .60 | 300 |

3. Direct Combustion and Gasification

Woody biomass (timber and crop residues) are used for these processes. In the analysis, 25% to 50%, depending on soil quality, of the residues have been left on the ground for soil amendment. A conservative BTU content of 7000 BTU/lb. has been assumed for the analysis. All conversion rates are, again, conservative, and based on existing performance of pilot projects and commercially available units. The end use energy equivalents reflect efficiency of conversion, but not residue collection or transportation.

WOOD - 7000 BTU/lb. Yield varies from region to region from 1000 to 7000 lbs/acre. [8] The analysis is based on regional timbering practices, w/use of residue only. Under current market conditions, energy cannot compete with lumber production. 7000 BTU's is assumed for the analysis to be on the conservative side and account for wet wood.

| wood | BTU/lb |
|---|---|
| cedar | 7780 |
| cypress | 9324 |
| fire | 8438 |
| hemlock | 8056 |
| pitch pine | 8308 |
| yellow pine | 8927 |
| white pine | 8308 |
| ash | 8246 |
| poplar | 8311 |
| beech | 8151 |
| birch | 8019 |
| elm | 8171 |
| hickory | 8039 |
| maple | 7995 |
| black oak | 7587 |
| red oak | 8037 |
| white oak | 8169 |

RESIDUES - 7000 BTU/lb. Yield varies with region, these are averages.[9]

| crop | yield |
|---|---|
| corn | .95T/A |
| small grain | .93 |
| rice | 2.17 |
| sugar cane | 1.78T/A |
| grass seed | 3.15 [10] |
| sorghum | .35 |

The following are technologically available options for bio-energy conversion. Choice will depend upon local conditions, as related to energy need.

Option 1. Co-fire with oil - equiv. 2 barrels /T [11]
Option 2. Co-fire with natural gas - equiv. 13,600$f^3$/T [12]

Option 3. Direct fire to electricity - 1235kwh/T (30% eff.) (8.5lbs steam/hr) [13]

Option 4. Gasification; gas to electricity - 944 kwh/T (23% eff.) [14]

What follows is an application of the preceeding conversion assumptions to three counties in the United States. Note energy potential as compared with energy consumption. [15]

Yamhill Co., Oregon [16]

1. Anaerobic Digestion

6000 Dairy Cattle (@ $14.8f^3$) $63800f^3$/day
1200 Hogs (@ $2.12f^3$) $2544f^3$/day
5000 Beef Cattle (@ $15.7f^3$) $78500f^3$/day
2,350,000 Chickens (@ $.06f^3$) $141000f^3$/day
830,000 Turkeys (@ $.32f^3$) $255600f^3$/day
daily total $5.7 \times 10^5 f^3$
monthly total $8 \times 10^6 f^3$
yearly total $2.4 \times 10^8 f^3$
electric generating potential $4.7 \times 10^5$kwh
existing county consumption gas: $1.1 \times 10^8 f^3$
electric: $4.3 \times 10^{10}$kwh

2. Fermentation

1000 AC orchards (apples) 140,00[illegible] gal
10,500 AC Fallow land (corn) 2,247,0[illegible] gal
per year ethanol $2.4 \times 10^{[illegible]}$ gal
existing county cnspt. gas per year $8.0 \times 10^{[illegible]}$ gal

Direct Combustion and Gasification

275,788 AC Forest Residue at 430T/A $1.18588 \times 10^8$T
17,225 AC Grass seed res. 3.15T/A 548258T
48,000 AC Wheat Residue .93T/A 44640T
5,500 AC Oat Residue .93T/A 5115T
4,250 AC Barley Residue .93T/A 3952T
2,650 AC Corn Residue .95T/A 2517T
$1.1 \times 10^5$ T
Soil Amendment - $2.7 \times 10^4$ T
$8.3 \times 10^4$ T
Forest $1.3 \times 10^8$ T
Total Residue $1.3 \times 10^8$ T

Option 1. Co-fired with #6 oil = $2.6 \times 10^8$ barrels
2. Co-fire with nat. gas = $1.76 \times 10^{12} f^3$
3. Direct combustion to elec. $1.69 \times 10^{11}$kwh
4. Gasification to elec. $1.23 \times 10^{11}$kwh
Present consumption in electricity $4.2 \times 10^{10}$kwh
" gas $1.1 \times 10^8 f^3$

Palm Beach Co., Florida [17]

Anaerobic Digestion

8000 Dairy cattle (@ $14.8f^3$) $118400f^3$
6000 Beef cattle (@ $15.7f^3$) $94200 f^3$
per day $2.8 \times 10^5 f^3$
per month $6.4 \times 10^6 f^3$
per year $7.7 \times 10^7 f^3$
County consumption per year $5 \times 10^9 f^3$

Fermentation

With 10% Diversion of existing sugar market
25,300 A of sugar cane at 555 g/A $1.4 \times 10^7$g
County Consumption of gasoline $2.5 \times 10^8$g

Direct Combustion or Gasification

253,000 AC cane residue 2T/A 506,000T
51,000 AC corn residue .95T/A 48,500T
Total $5.5 \times 10^5$T

Option 1. Co-fire with #6 oil = $1.1 \times 10^6$ Barrels
2. or w/ nat. gas = $7.5 \times 10^9 f^3$ gas
3. Direct combst. to elect. = $6.848 \times 10^8$ kwh
4. Gasification to elect. $5.234 \times 10^8$ kwh
Present elect. consumption $1.3 \times 10^9$ kwh

San Saba Co., Texas [18]

Anaerobic Digestion

236,000 Turkeys at $.32f^3$per animal 75520 $f^3$/day
9,000 Hogs at $2.12f^3$per animal 19080
$9.4 \times 10^4 f^3$/day
monthly total $2.8 \times 10^6 f^3$
yearly total $3.4 \times 10^7 f^3$
yearly consumption $8.5 \times 10^7 f^3$
electric potential $2.0 \times 10^6$kwh
present electric consumption $2.6 \times 10^7$kwh

Fermentation

16,000 AC into prod. (sorghum) 500 gal/A $8 \times 10^6$
per year current consumptions $3.8 \times 10^6$ gal

Direct combustion and gasification

| | | |
|---|---|---|
| Pecan Shells | | 3250T |
| Sorghum | 1000 AC(1.) = | 1000T |
| Oats | 7500 AC(.5) = | 3750T |
| Wheat | 4900 AC(.5) = | 2450T |
| Rye | 500 AC(.5) = | 250T |
| 265,000A Brushy Forest | $1.1 \times 10^4$ T/yr. | |

Options 1. Co-fired with #6 oil = $2.1 \times 10^4$ bar.
2. or with natural gas = $1.455 \times 10^8 f^3$
3. Diret combustion to elec. $1.3 \times 10^7$ kwh
4. Gasification to elec. $1.0 \times 10^7$ kwh

Current consumption in electricity $2.6 \times 10^7$ kwh

CONCLUSIONS

Each of the counties studied has the potential to provide at least a portion of the present energy requirement from bio-energy, therefore reducing fossil fuel dependence. However, the bioenergy development potential and land use impacts are in each case tied to existing local conditions. A closer look at the counties illustrates this point and identifies some potential issues which could constrain development.

San Saba County, Texas

The most promising bio-energy potential for San Saba is extended cropping of sweet sorghum for conversion to alcohol. When alcohol vehicles are available, the county could be self-sufficient. At present, the county could reduce gasoline use by 20% and export over $7 \times 10^6$ gal. Direct combustion of residues to provide electricity or co-firing in existing facilites to reduce gas and oil consumption would reduce electrical energy by at least 50%, totally reduce gas use. Methane potential is more than half the natural gas consumption.

Constraints to development are soil conditions, existing market conditions and competition from other uses. The existing land use in the county is primarily grazing (79% [19]). These grazing lands provide habitat for deer and turkey, and recreational income from hunting leases. Of the land available for extended cropping, the limiting factors are soil erosion and limited rainfall. Production would require terraining and irrigation expenses. Residue removal, if mismanaged, could increase the erosion potential and effect water quality.

Palm Beach Co., Florida

Palm Beach County is at this time using biomass derived fuel. Bagasse, a fiberous by-product of the cane industry is co-fired or fired alone to heat the boilers for sugar production. Use of this residue, along with cane and corn tops could make the sugar industry energy self-sufficient. The urban sector of the county (only 6.2% of the land area) uses 70% of the energy. While it is unlikely that the county could become energy self-sufficient from biomass, the ag sector with only 9% of the present energy use could help the urban coastal area reduce fossil consumption by "exporting", when and if that were economically feasible.

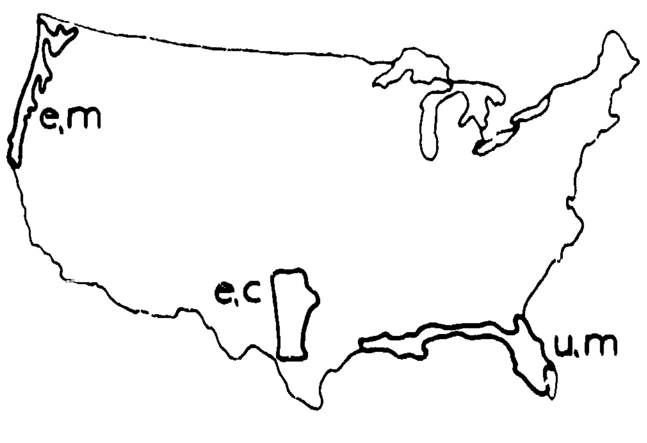
Increased production from land area is unlikely, as the county is extensively cropped, and the urban area is spreading from the coast. Although the planning commission has zoned the sugar area as an agriculture preservation area, and wooded coastal lands are more desirable for urban growth, the cost of land is increasing throughout the county. As the price increases on the coast, the inflationary trend extends to the tree-less muck lands used for sugar production . In 1970, an acre of sugar land cost $800, now the price is $3000 per acre. The other alternatives to increased production for energy are technological advances (more yield per acre) and a reduction in sugar production. At present prices this is not likely. When the consumer is willing to pay more for alcohol fuel then sweets, this will occur. At that time, those industries which support the sugar processing market could be affected.

Residue removal is no threat to soil or water quality. Sugar is a perennial and does not require yearly planting. The muck soil and flat, wet, terrain leaves little chance for erosion. .Increased combustion facilities could affect air quality. This is more an economic constraint to development than a technological or environmental problem. Ash, on the other hand, (that noncombustible portion of the residue) could pose waste disposal problems given the high cost of land in the county.

Yamhill County, Oregon

Yamhill county is typical of the Northwest coastal region. There is tremendous variation in soil and vegetation type and water availability within the county. The present land use is 37% forest and 33% cropland--a good mix for integrated biomass potential. Without reducing current agricultural and silvicultural output, the county could export electricity, methane and 5% of the alcohol produced (after reducing gas consumption by 20%/year).

There is potential to expand energy production by improving class two and three lands. (Still in the arable region, without getting into the marginal class IV-V lands) the constraints are erosion and flooding potential. Again, these are economic constraint.




Key: e = erosion, m = market, u = urban, c = climate

Fig. 2 Local Constraints

SUMMARY

The bio-energy potential exists, and the conversion technologies are available and cost effective. The problem is matching existing need with the potential. For example on-farm anaerobic digestion seems to be, from this analysis, a promising activity, but the costs of compressing, storing and transporting the gas could prohibit its dispersion throughout the community. The economic alternative, though not as energy efficient, is on-farm electrical generation. The most likely outcome is on-site conversion and use without much potential for reducing fossil use for other areas.

Alcohol fuel production from surplus crops will not cause any major land use conflicts. Problems will come with over cropping or cropping on marginal land.

Direct combustion may be limited by increased cost of liquid fuel for collection and transportation, with the exception of those industries which can use process residues. This seems the most likely candidate for increased demonstration projects and local assistance. Direct combustion will cause air quality and disposal issues. Residue removal could cause erosion and soil depletion, therefore water quality constraints.

It is not direct use, but abuse of land that causes problems. With careful management of the land, however, the resource potential can be realized without any detremental effects to soil or water quality and existing land use practices. The most effective means of assuring this is user participation in the planning process. Cooperation between all agencies and individuals who make land use decisions can increase community awareness of bio-energy potential. By comparing this potential to the reality of environmental, economic and end-use constriants, the local resources can be used in the most effective manner, without adverse consequences. This can be achieved by workshops and demonstration projects at the local level. Policy at the national level should be directed toward this goal.

REFERENCES

[1] U S Department of Energy: Domestic Energy Use, Energy Information Administration, April 1979.

[2] Institute of Electrical and Electronics Engineers, Inc.: U.S. Energy Data Book, 1979.

[3] Personal Communication with Bernadette Miphlki, EIA, DOE, March, 1980.

[4] U S Department of Commerce: Climatic Atlas of the U.S., Environmental Science Services Administration, 1977.

[5] U S Department of Energy: "The Energy Consumer", Alcohol Fuels, Office of Consumer Affairs, January 1980.

[6] Personal Communication May 1980 with Greg Mann, Los Alamos Scientific Laboratory; Los Alamos, New Mexico. Bernie Neenan, Solar Energy Research Institute; Golden, Colorado.

[7] U S Department of Agriculture and Development Planning and Research Associates, Inc.: Small-Scale Fuel Alcohol Production, USDA, March 1980.

[8] A.B. Curtis, US Forest Servie as quoted from MITRE Corporation: Silvacultural Biomass Farms,, Technical Report Number 7347, May 1977.

[9] Silvio Flaim and David Urban: The Costs of Using Crop Residues in Direct Combustion Applications, SERI, March 1980.

[10] Frank Coklin: Agriculture Experiments Station Oregon State University Circular 675, March 1979.

[11] Ralph Chandler: Tri-Valley Peach Pit Burning Project, California Energy Commission, July, 1979.

[12] Ibid, 11

13] U S Department of Energy: Environmental Data Energy Technology Characterizations, OTI, Jan. 1980.

14] John Goss: Pilot Plant Gasification Test, CEC, June 1979.

15] Consumption figures for Palm Beach are from Kevin Henderson, Treasure Coast Regional Planning Council, 1980.

16] Ron Bunch, Yamhill County Planning Department, 1980.

17] Clayton Hutchinson, Palm Beach County Agriculture Extension Office, 1980.

18] Jack B. Miller, Mayor, San Saba, Texas, 1980.

19] All land capability information is from the USDA 1967 Conservation Needs Inventory.