INTEGRATED RENEWABLE ENERGY/ORGANIC WASTE RECYCLING SYSTEM:

Final Report, July 31, 1982

Prepared by:

Robert A. Hamburg, Project Director

and

Steve Davenport

Prepared for:

U.S. DOE, Region III,
Appropriate Energy Technology Small Grants Program,
1982

Proposal No.: 80-WV-0057-D-35,771-11

Grant No.: DE-FG-43-80R302456

Abstract

Two operating systems for integrated recycling of organic materials are described. The systems include Chinese water-pressure design biogas digesters/solar greenhouses/ and algae and aquatic plant ponds-all in passive symbiotic relationships with a minimum of technological sophistication. Economic, Financial and Net Energy Analyses of these systems have been done with concern toward long term environmental effects. A discussion of fish ponds and fuel alcohol production is also included since they offer much potential for expanded integration.

Table of Contents

Acknowledgements

A complete enumeration of those who have been of assistance with this work would be overwhelming. However I would like to especially note the help of; U.S. DOE Region III's Appropriate Energy Technology Small Grants Program for demonstration grant funds; Tim and Sharon Urbanic for accepting this innovative DOE funded system into their farm; Tom and Lynn Degen for construction assistance and operation of the pilot system; Dr. Allen and Dorothy Hamburg for financial support for the pilot system; Dr. Paul Moe, late of the W.V.U. Biology Dept. for inspiration and support; Jim Rosencrance and the W.Va. Environmental Health Services Laboratory; Dr. John Brough and the W.Va. State Hygenic laboratory; Dr. Thelma Njaka and the Animal Disease Laboratory of the W.Va. Dept. of Agriculture; Drs. Gary Bissonette, John Sears and Robert Anderson of W.V.U..

I would also like to thank Bill Swearingen, Rex Rivard, Miriam Murrell, Alex Fazio, Rusty Weaver, Paul Shaner, Alain Perineau, Lynn Wildoner, James Fuss, Dave Moser and B-Bond Industries, Chris Tobias, Tildon Riley, Art Dorland, Steve Davenport, Michael Bailey, Tim Larroway and Jane Thomas.

Foreword

I. In an effort to simplify communication with the majority of expected readers, I have attempted to use English measurements throughout this report except in regard to food values where kelocalories are more commonly understood.

II. Parenthetical numbers throughout the text refer to the reference list.

TABLE 1. Energy Use in the U.S. Food System, x10^{12}kcal after (195)

	1940	1970	% increase
direct fuel use	70.0	232.0	331%
fertilizer	12.4	94.0	758%
food processing industry	147.0	308.0	209%
food processing machinery	.7	6.0	857%
paper packaging	8.5	38.0	447%
glass containers	14.0	47.0	336%
steel and aluminum containers	38.0	122.0	321%
transportation fuels	49.6	246.9	498%
trailer and truck manufacture	28.0	74.0	264%
Totals	368.2	1167.9	317%

TABLE 2. 1977 Output and Selected Farm Inputs as % of 1960 Levels (after 35)

Labor	Farm Real Estate	Mechanical Power and Machinery	Fertilizer	Total Inputs	Farm Output
49%	97%	20%	298%	102%	133%

Section 6

Introduction

The sun is the source of nearly all of the energy available (the exceptions being geothermal, the preponderance of tidal, and nuclear energy) to the inhabitants of Earth. This includes the sunlight of millions of years ago in the form of fossil fuels, and today's sunlight in the form of food, fodder, and firewood. Green plants are the only living organisms able to use solar energy directly and they provide all of the energy which drives the life support systems of Earth. Fossil fuels are the partially decomposed remains of the plants and animals of eons past. Human beings are the only living organisms able to use this stored solar energy (with the exception of petroleum consuming bacteria) and it currently provides a large contribution to the upkeep of much of civilization. Unfortunately the Earth's life support systems evolved over millions of years and seem increasingly unable to co-exist with many of the facets of civilization that have resulted from the unlimited exploitation of fossilfuels, as exemplified by modern industrial society.

Less than a century ago, yearly photosynthesis provided over 90% of humanity's fuels. (21) Indeed, even today firewood still provides fuel for a third of the world's population. (28) In industrialized societies the recent easy availability of fossil fuel energy has led to many people leaving the land and a general lack of awareness of biological realities relating to size and diversity. This has resulted in the illusory advantages of large-scale, centralized, over-specialized production systems which make large populations dependednt on the oligarchical control of distant fuel and material supplies.

The unsustainable, non-renewable, and environmentally destructive nature of our current lifestyle is nowhere more basic than in the U.S. food system where over ten times as much fossil fuel energy is required by the system as is embodied in the food consumed. (29) Every year in the U.S. about 13.5×10^{15} kcal of solar energy is fixed by grren plants of which about 6.9×10^{15} kcal is harvested as agricultural crops or forest products. (157) (Compare to 18x10 kcal energy consumed. (157)) Tables 1. and 2. show that fossil fuel supplements to the food system heve increased tremendously in the recent past. The multitude of complex fossil fuel inputs to the food system currently account for about 16.5% of total U.S. Energy consumption about [illegible] fuel/person/year to provide about 1.2x10^6 kcal food energy/person/year.(159)

The need for a sustainable society based on renewable resources and in tune with the natural mechanisms of the environment has been well described by numerous researchers and writers. Commoner's interrelated Laws of Ecology:

Force - beginning of sentence?

1. Everything is connected to everything else
2. Everything must go somewhere
3. Nature knows best
4. There is no such thing as a free lunch (45)

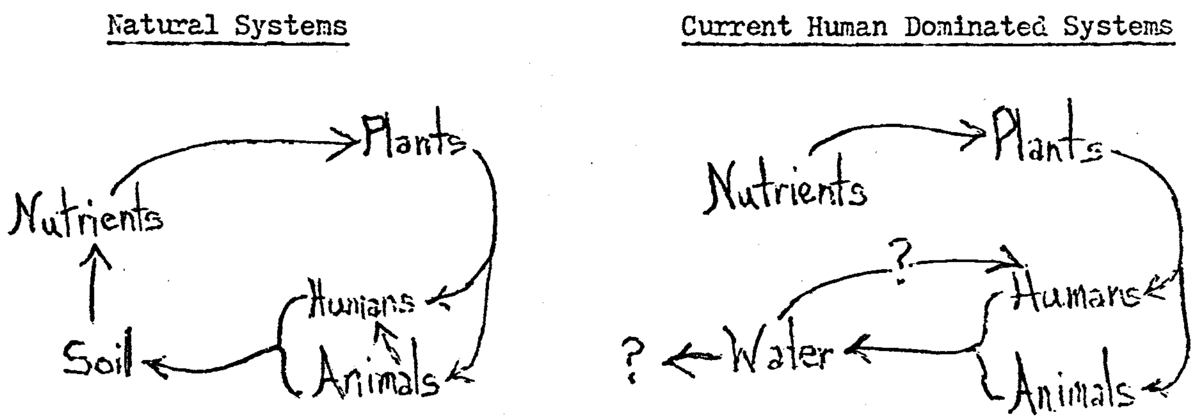
force themselves upon us as the current production/consumption/disposal society begins to reach, and hopefully recognize and act upon the ecological limits of existence. These limits are largely defined by the amount of solar energy fixed on Earth, the energy flows through the Earth's ecosystems, and the ability of the Earth's ecosystems to absorb the wastes of human society and to connect the wastes of nature into material for new growth."Evolution fitted the new species together in ways that not only conserve energy and the mineral nutrients utilized in the life processes, but also conserved the nutrients by recycling them, releasing more oxygen and making possible the fixation of more energy and the support of still more life." (220) Within the Laws of Ecology, there is still great potential for humanity to work with nature to evolve biological systems which stretch the ecological limits to provide more food and energy without stressing the natural recycling system.

While the theoretical maximum for photosynthetic efficiency is 5-6%, year-round agricultural efficiency over 1% is unusual. (21) Research with aquatic plants and algae over the last 20-30 years has demonstrated photosynthetic efficiencies which approach the theoretical limits.

Energy flows through the Earth's ecosystems via the various food chains. The actual amount of energy transfered varies widely but figures of 10-20% of energy entering herbivores transferred to primary carnivores, etc., are generally accepted. (220) Much of the original energy entering animals is still present in their waste products. These wastes plus the energy in dead but uneaten green plants support the growth of the organisms of decay which prepare the materials for utilization by new growth. Biological management of the organisms of decay as a final link in the domesticated food chain can hasten decomposition of organic materials while the residual energy is extracted in forms suitable for human use. Utilization of this biomass energy does not affect atmospheric heat (218) and CO2 levels (61) because its combustion is balanced by new growth.

A large part of modern societies' stress on the recycling systems from their short-sighted attempts at waste "disposal".

Figure 1. (after 67)



Organic waste waters can be biologically managed to increase usable photosynthetic growth and the return of nutrients to the soil. "The optimum in waste use would be an essentially closed, self-sustaining farm unit with few inputs apart from the sun and water." (67)

"Virtually all net energy production of the Earth is consumed annually in the respiration of organisms other than green plants, releasing carbon dioxide, water, and the heat that is reradiated into space...The energy that is not consumed is either stored in the tissues of living organisms or in humus and organic sediments." (220) Humus is the organic component of topsoil and the energy stored in it is available to support new growth. Generally the more energy thus stored, the more new growth can occur. "For centuries, agricultural realists have known that the soil's potential for crop production is a function of its organic matter content." (154) Organic matter improves soil structure and tilth, increases water infiltrationand storage, thus increasing resistance to erosion and crusting in beating rain (196) heightens

TABLE 3. Soil Organic Matter Changes Related to Fertilizer and Organic Manure Treatments for a Metea Loamy Sand Growing Silage Corn (126)

Annual Treatments N-P2)5-K2)=Manure lb. acre	tons/acre	Silage tons/acre no irrigation 1963-1973	irrigation 1974-1976	% Soil Organic Matter 1968	1976
160-40-40-0		13.5	23.3	2.05	1.63
160-140-190-0		15.0	24.5	2.05	1.70
10-40-40-10		14.3	19.6	2.12	2.07
10-40-40-20		14.8	23.5	2.28	2.20
10-40-40-30		15.6	23.9	2.96	2.83

TABLE 4. Soil Organic Matter Changes as Related to Fertilizer and Manure Treatment for a Matea Loamy Sand Growing Corn (Grain). (126)

Annual Treatments N-P205-K20-Manure lb. acre	tons/acre	Bushels/Acre no irrigation 1963-1973	irrigation 1974-1976	% Soil Organic Matter 1965	1976
160-40-40-0		85	141	1.98	2.03
160-190-190-0		78	147	2.07	1.97
10-40-40-10		83	129	2.10	2.13
10-40-40-20		83	143	2.38	2.40
10-40-40-30		82	147	2.63	2.83

cation exchange, and stabilizes the mineralization rates of nitrogen.(154) The effects of organic soil matter on productivity can be seen in Tables 3 and 4. The application of organic materials to the soil will be considered in further detail in Section 10.

Symbiosis is a biological term used to describe the relationship between two (or more) species of organisms when their living together is advantageous or necessary to both. Humans have established a symbiotic relationship with dogs or dairy cattle. The same approach can be applied to the afrementioned possibilities for ecologically stretching the biological limits of Earth's life support systems. This account describes some of the possible interrelationships.

 Final RE Rept 12
7/31/82

Bio-Economics

These times of high unemployment along with high inflation have caused many problems for economic theorists. As this review is to deal with the "economics" of symbiotically integrated recycling systems, and as I am certainly a layman in the field, it is necessary to present the thoughts of several other persons which relate closely to this situation. Lester Brown in a Worldwatch Paper on new sources of global economic stress, suggests the following:

"While most economists recognize that something is wrong, few have had much success in determining exactly what. Increasingly preoccupied with the economic indicators, short-term forecasts, and econometric models, economists appear not to have noticed that the expanding global economy, fueled by both rising affluence and population growth, has begun to outstrip the carrying capacity of some of Earth's biological systems and to deplete some of its key resources. Many of our current "economic" problems are rooted in this deteriorating ralationship...

Four biological systems-fisheries, forests, grasslands, and croplands-form the foundation of the global economic system. [Economists] lack of ecological awareness has contributed to some of the shortcomings in economic analysis...

The changes involved in accomodating ourselves to the Earth's natural capacities and resources suggests that a far-reaching economic transformation is in the offing. The origins of the change are ecological, but the change itself will be social and economic, and the processes for achieving it will be political...

Unless economists can gain a better understanding of our economic dependance on the Earth's natural systems, they will be hard pressed to advise political leaders wisely. We may end up [already are] treating the symptoms of our economic maladies rather than the causes (28)."

In a far-sighted work of the early 1950's economist K.W. Kapp presented an introduction to the "social costs" of private business enterprise. He defined these costs, commonly called "externalities" as,

"any cost incurred by business activity which falls upon third persons or the community at large and is not therefore accounted for by business decision-making based upon the principle of profit-making without regard to possible negative effects." (109)

He shows that "social costs" are major, typical, regular, and very significant, and include,

"air and water pollution, soil erosion, destruction of wildlife and of ecological balance, spoilation of non-renewable resources, impairment of human beings through occupational diseases, radiation, unemployment, the costs of duplication and excess capacity, planned obsolesence, sales promotion, theretardation of science and its harnessing to the instruments of destruction, society's over concentration on urban centers and sacrifice of human well-being to the processes of production. (109)"

Barry Commoner suggests that,

"The costs of environmental degradation are chiefly borne not by the producer, but by society as a whole in the form of "externalities . A business enterprise that pollutes the environment is being subsidized by society; to this extent, the enterprise, though free, is not wholly private." (45)

Thus a large portion of government in modern society is devoted to repair and prevention of many social losses caused by modern industrial activities. (109)

Some social costs may be measured in dollar terms of loss of earnings or cost of reclaimation, but many of these costs "are highly complex and composite in character and can be evaluated only interms of the importance which organized society attributes to both tangible and intangible values involved." (109) Social costs are often widely dispersed through the community and "are not such that an individual can measure and claim compensation for, let alone anticipate and avoid." (109)

It is not that measurement is unimportant, but rather that more important than precision in measurement is selection of goals. (109) In many situations some data is available but this is unsatisfactory because it is not only incomplete but also misleading because the focus is only on those values which can be estimated in dollars. (109)

"To leave social losses out of account because they are 'external' or'non-economic' in character would be equivalent to attributing no or 'zero' value to all social damages [or benefits] which is no less arbitrary and subjective a judgement than any positive or negative evaluation of social costs." (109)

"The basic causes of social costs are to be found in the fact that the pursuits of private gain places a premium on the minimization of private costs of current production." (109) Private enterprise investment decisions are based on profit and productivity which are increased when some of the costs of production are shifted to the society at large.

Tom Bender suggests that;

"Value judgements seem ephemeral when considered beside profit and loss statements, yet profit and loss statements hold little meaning when viewed from thenext generation or when viewed beside the loss of irreplaceable physical realities upon which continuing support of our lives must depend." (18)

Hazel Henderson concludes that the,

"basic paradigm and linguistics.. [of economics] limit it to the rather narrow range of human affairs where its methods are appropriate: thelegitimate areas of keeping accounts between small-scale enterprises, proper bookkeeping, etc." (92)

It is largely the "zero" valuing of social costs which has led to the illusory "economics of scale" which have resulted in increasingly large installations and more

TABLE 5 (after 150)

Farm size (acres)	Interest on operating capital (6% norm)	Fertilizer discounts	Insecticide discounts	Dusting & spraying discount	Total difference from base costs/acre
80 ↓ 3200	6.88% ↓ 5.9 %	0% ↓ 10%	0% ↓ 14%	0% ↓ 25%	$0.56 ↓ -$6.62

TABLE 6 Results of fixed investment (rs 1200 M) (after 166)

	Biogas Digesters	Conventional Electric Power Stations	Urea Fertilizer Plant
Capacity	30KW (village state)	60 MW (say)	500,000 tons
No. of Units	40,000	10	1
Nitrogen Production	58,000	--	230,000
Foreign Capitol	--	some	Rs 500M
Employment	100,000 +	m.d.	1,000
Energy	1,200MW	approx. 600MW	35MW (consumed)

centralized control of production and supply. While this system may increase current profit and productivity, it does not necessarily lead to efficiency. For instance, in 1967 the USDA found that the most efficient farms were fully mechanized one or two man operations but that California vegetable production was dominated by farms which were seven times larger. (214) Table 5 also shows that profitability has little to do with efficiency.

The"economics of large scale" have been no where more comprehensively employed than in the area of energy supply. Temporary convenience (and industry propaganda) has motivated the general populace to acceptance of large-scale, centralized, oligopolistic control of energy supply. This system is noe coming under a re-evaluation due in part to the fact that investments in large-scale energy systems proposed by the Department of Energy and energy monopolies would consume three fourths of all private investment capital in the U.S. (83) Table 6. compares three possible alternatives for the investment of 1200 million rupees ($150 million) in India. Though not completely applicable to the U.S. situation, this table does indicate some of the impacts of organic recycling proposed in this report.

In regard to organic recycling/renewable energy systems, Tom Abeles and David Ellsworth point out that;

"Previous [and current] energy policies and development strategies have been predicated on centralized control of the harvesting, transportation, processing and marketing of energy feedstock...The very nature and distribution of the biomass feedstock materials however, requires a change in this strategy. The nature and distribution of biomass feedstocks precluding centralization include the following,

a) 90% of animal manure is on farms with less than 1000 head of cattle equivalent
b) differing markets for the biomass and end products including bioconversion to a number of micro- and macro-scale uses, and
c) problems associated with collection, transport and processing are site specific decentralized and not subject to oligopolic control."(1)

Even for standard sewage treatment "in the general situation, decentralized systems clearly have a significant advantage of centralized systems." (37)

"Monet-ary and fiscal policies that do not reflect energetic [and biological] realities inevitably generate instabilities in the marketplace." (16) Real inflation includes the rising effort of Andean villagers to gather firewood because of deforestation, the increased efforts of African farmers to produce food because of erosion (28) and the increased chemical nitrogen fertilizer required by American farmers because of increased run-off rrom organic-poor soil.

In the many hundreds of reports on this field that Ihave read, I can at most vaguely recall any emphasis placed on the following observation: If self-sufficiency holds any value then the labor, et. al., that must be expended to aquire the medium of exchange for goods purchased must be credited to/subtracted from the self-directed labor required to replace those purchased goods. (See also Sections 10-15)

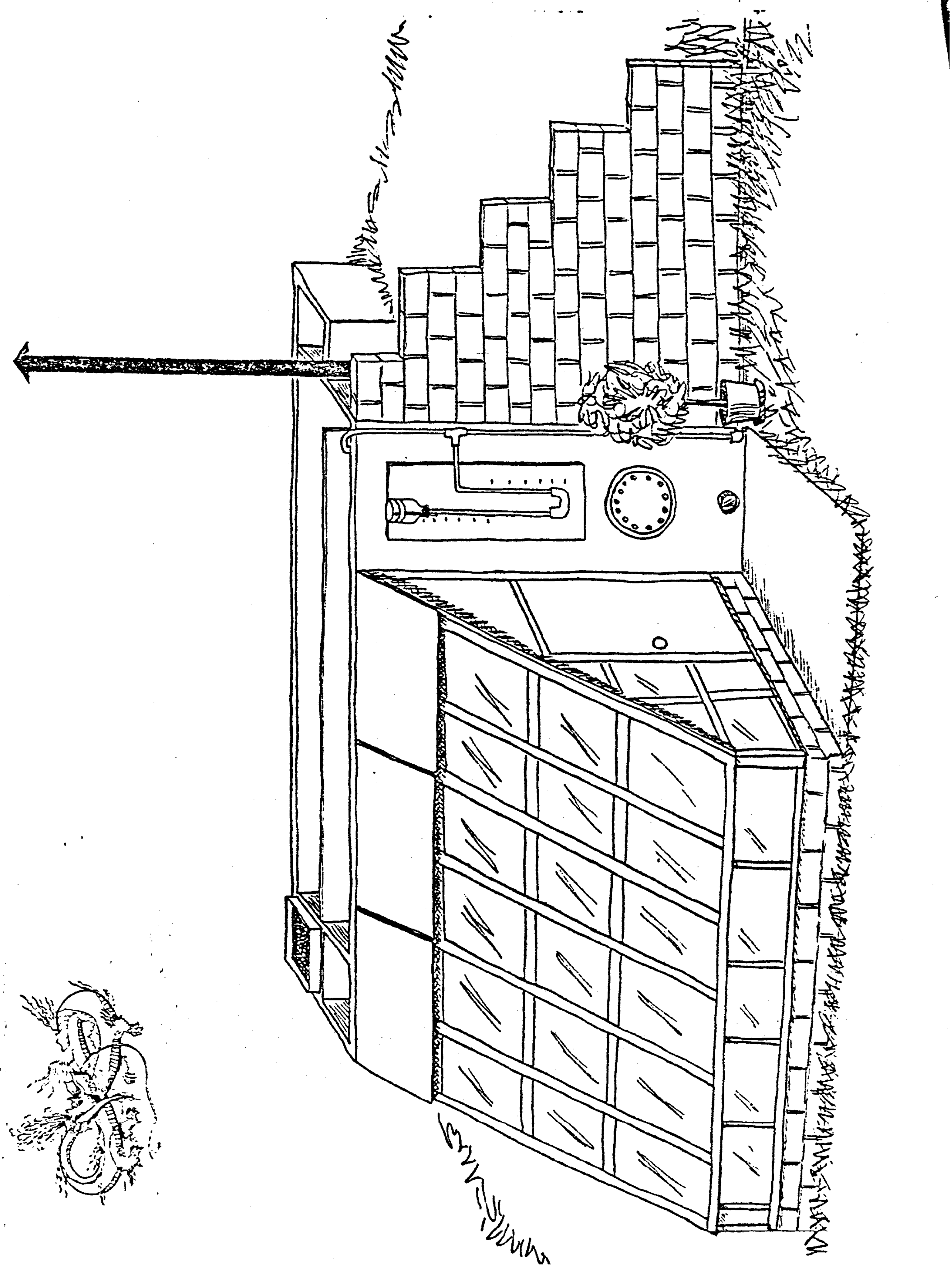
"Social analysts [economists] customarily try to weigh the import of political and technological forces on distribution of income and wealth", but they rarely consider the effects of ecological degradation which threatens those dependent on primary biological production. (28) The Earth's ecosystem's limited capacity,

> "to absorb waste cuts across virtually every sector of economic activity. At some point, the cost of environmental damage caused by a given economic activity can exceed the value of the product itself, though neither the producer or the consumer may realize this since the larger community bears the cost." (28)

Our monetary systems account for neither the work nor the value of work done "free" for us by biological systems. (16) Polluting production systems "borrow" from the environment and incur a debt to nature which gives an immediate savings to the producer. (45) What is needed is theinclusion of "biological capital" and energy accounting in decision-making analyses. (45) A final thought from Tom Bender's <u>Sharing Smaller Pies</u> describes our situation quite well.

> "Under conditions when great wealth is possible, our values and actions shift to take best advantage. When growth is no longer possible or desirable, our values and actions must adjust again to harmonize with new realities." (18)

1



Section-8

Preliminary Efforts-Draco I

Omega-Alpha Recycling Systems' Draco I was initiated as an attempt to give a concrete demonstration of some of the possibilities for symbiotically integrated organic recycling on small homesteads. The system illustrated opposite, is composed of a biogas digester, asolar greenhouse, and an algae/aquatic plant pond. It was constructed in 1979 at the goat-breeding homestead of Tom and Lynn Degen in central West Virginia.

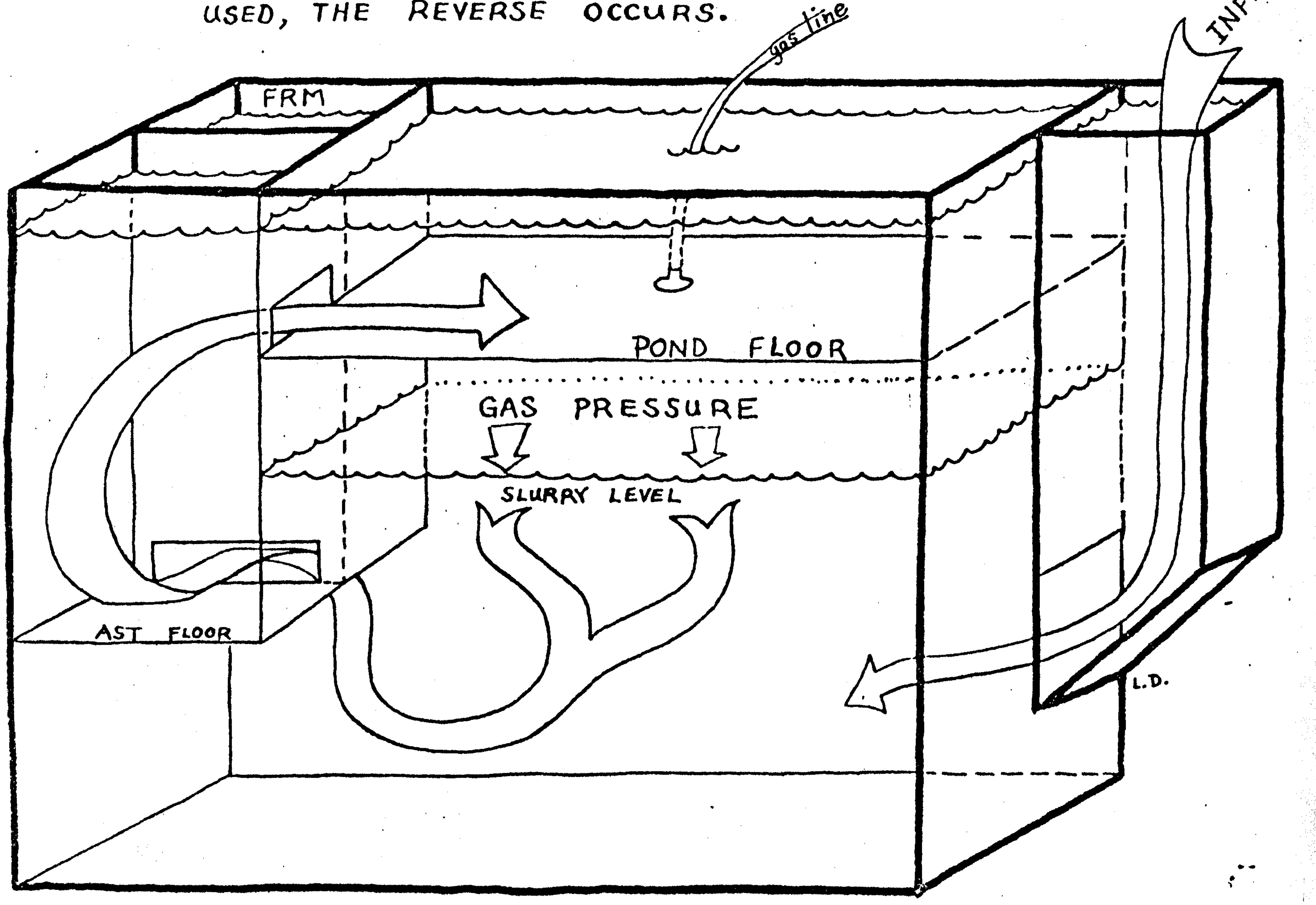
The digester is based on a flat-topped water-pressure design developed in the People's Republic of China. It was constructed of reinforced concrete footers, slabs and lintels, and reinforced concrete block walls. The concrete and block was rendered gas-tight using B-bond, a fiberglass reinforced plaster. Acid resistant Type V cement was used for making the B-bond applied to the inside of the tank because of the corrosive environment created by H2S and water vapor in the biogas. Internally, the tank is 4' wide, 8' high and 20' long. This gives a total volume of 640 cu. ft.^{3} and storage for up to 270 cu. ft.^{3} of gas.

Digesters in China are set entirely inthe ground operate adequately at ambient temperatures as low as 55°F . (48) Several steps were taken in this project to increase digester temperature and thus improve upon the efficiency of the basic Chinese design. All earth-bermed surfaces were first covered with three inches of polyurethane foam insulation to maximize heat retention. A vapor barrier and six inches of gravel with drain tiles were then placed around the insulation to ensure dryness and reduce heat loss to the soil. A 35' high, 7" in diameter thermosiphon also draws hot air from the greenhouse through ducts set in the floor of the digester.

The 7'x13' greenhouse covers most of the south wall of the digester. A reinforced footer was set below frost line with reinforced concrete block up to the surface. Rough-cut oak lumber was used for framing and siding, and the glazing is two layers of tempered safety glass. The side-by-side orientation of the digester and greenhouse allows them to complement each other without the danger of build-up of explosive gas mixtures which could occur with a greenhouse-enclosed dogester.

Durability was a major aim in design and construction of this installation.

⇨ SLURRY FLOW THROUGH FILTRATE RETURN MODULE INTO ALGAE SUPPORT TANK AND THEN POND. AS GAS IS USED, THE REVERSE OCCURS.



Materials costs were about $4500. and the system is expected to give service for many decades.

Operation

Greenhouse operation began in October 1979, and has been nearly constant since that time. With no auxiliary heating during winter, temperatures have been 25° to30° F above night-time lows, falling to 28°F when outside temperature reached -1°F.

In March or April, about four pick-up loads (5 tons) of the winter's accumulation of goat house bedding and manure is pitchforked into the digester through a port in the pond floor. To this is added 200-500 lb. of chicken house cleanings and about 2400 gal. of creek water. The top port is sealed and the high CO_2 content gas is released daily for two to four weeks. When methane content reaches about 50%, an excellent flame holds on two cooking burners and a mantle lamp (from Nepal and India).

From about one month after start-up to about one month after emptying, small loads of goat berries, whey, kitchen scraps, or canning wastes are added through the inlet tank. Adaquate stirring is accomplished with a simple wooden plunger used a couple of minutes a day.

Gas production averages about 300 cu. ft./day in August. Assuming a methane content of 60% methane, use of the biogas is equivalent to the average natural gas used during this period by other area residents.

Digester temperatures rose from 67°F in early May to 85°F in mid-summer. These operating temperatures and the addition of more organic materials, are credited for sustained moderate gas production. This is generally more appropriate thanthe short-term peak production which would be expected from a strict batch digester at constant temperature.

In fall the tank is emptied onto garden and fields. Supernatant/pond liquid flows through a garden hose siphon. Sludge is emptied through a gate valve near the base of the digester and a 4" flexible sewer line. The undigested straw and settled solids are pitchforked out the 2' cleaning port. Little odor is associated with this task because a) the volatile solids in the manure are consumed by the digestion process, b) most ammonia nitrogem is dissolved in the supernatant and sludge, and

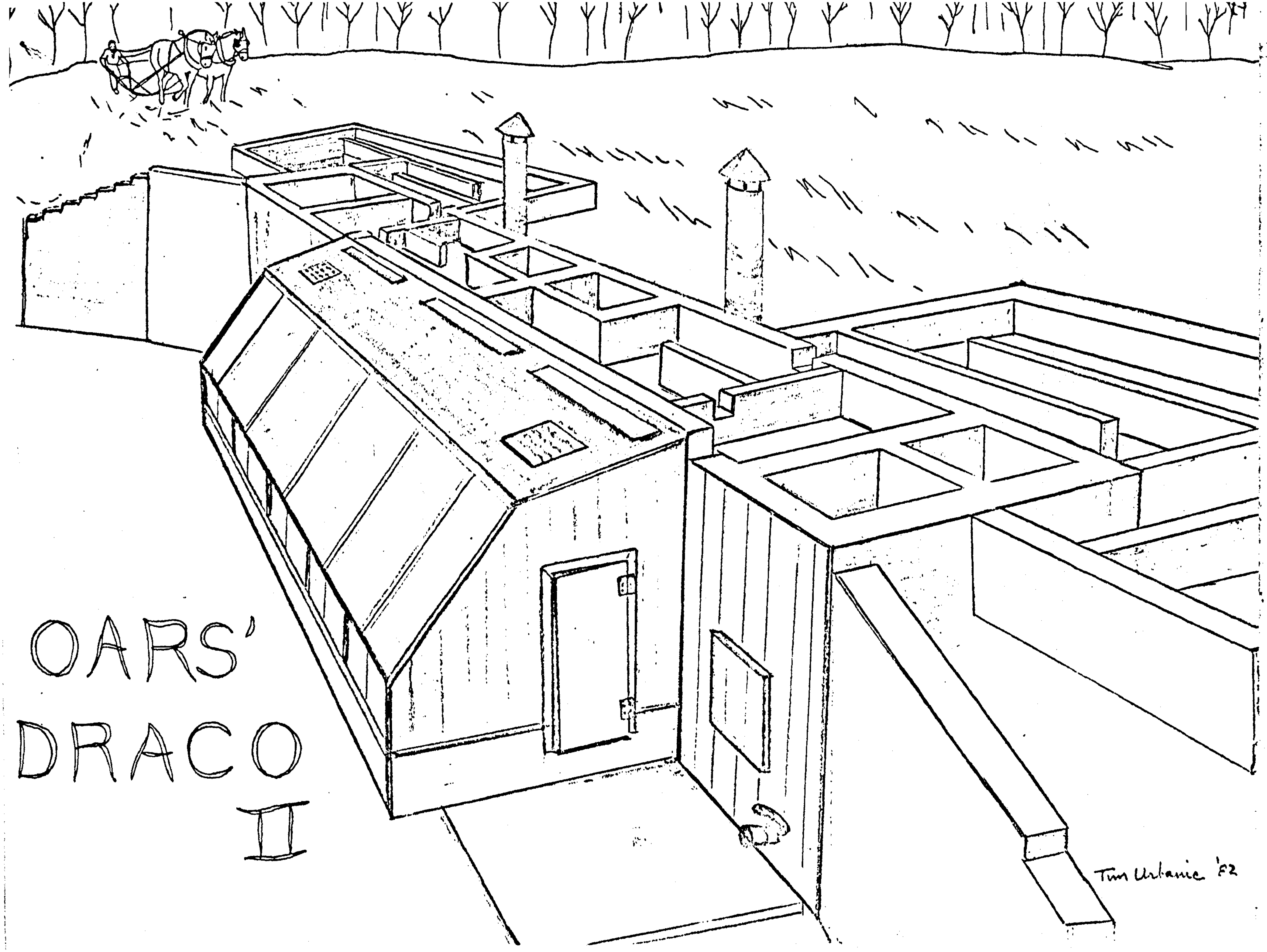
c) the large openings into the tank allow substantial air circulation.

The integration of an algae and aquatic plant pond was perhaps the most innovative aspect of this project. At the time I had found litte information on related efforts.

The open pond covered only the top of the digester and was to be used only during warmer months. The liquid flowing into it was dark brown but almost odorless. It was, however, to rich for the duckweed and water hyacinth which was stocked and survival time was at most 2 weeks. Water hyacinth did thrive in an aquarium which started at about 50% pond liquid and water and finally reached nearly 100% pond liquid.

During the warment part of the summer, the pond was covered with a thick green mat of assorted euglena, protozoa, and green algae. This growth though profuse, is not easily harvestable even in high technology situations.

The primary parameter for determining the success of the system is incorporation into the lifestyle of its owners. As a biological system, it was expected that three to five years would be necessary to approach utilization of the system's potential. Draco I is now in its third year of operation/life and greenhouse and gas production continue to rise. Pond production would require expansion of the surface area by 3 to 4 times and this has not been possible to date.


OARS' DRACO II
Tim Urbanic '82

Section 9-1

Department of Energy Project-Draco II

The Department of Energy's Region III, 1980 Appropriate Energy Technology Small Grants Program has provided the opportunity for installation of another, much expanded system. This unit (illustrated on the facing page) is installed at the central West Virginia farm of Tim and Sharon Urbanic. It is composed of two 6'x8x26' digesters (1248 ft.^{3} total volume and 624 ft.^{3} gas storage each) an 11'x38' solar greenhouse, and two 300 ft.^{2} algae/aquatic plant ponds. The same basic design, component orientation, and construction materials and techniques were used as in the first system. Major changes included insulation of the digesters' ceiling and exposed walls; increased thermosiphon diameter with inclusion of photovoltaic fans; and expansion of the algae/aquatic plant pond surface area.

Project construction began in March, 1981 and was finally completed in June, 1982. Greenhouse operation began in November, 1981, and has been continuous since then. Winter temperatures of -20°F pulled the greenhouse temperature down to 27°F. (It should be noted that this was with the digesters empty and their temperatures nearly ambient. When they are filled with about 14,000 gal. of digesting slurry at 70-80°F, greenhouse freezing will be unlikely even in the coldest of weather.)

The loading of manure into the digester began in January 1982. Approximately 9 tons of manure (about $\frac{1}{4}$ bedding) was loaded by May, 1982, but the extremely dry spring weather conditions had caused a water shortage. (This should not pose a problem in future years as a spring fed line will carry winter and early spring's ample water supply to the system.) A pump was finally acquired to get creek water to the digesters. There were a number of leaks at the base of the digester and through hairline cracks in the B-bond. Nearly all of these have been sealed by the slurry. Unfortunately there is one spot in the fully loaded and closed digester which is above slurry level and is causing loss of gas pressure. This will be remedied in August 1982, and full operation of digester and ponds is expected to begin then.

It must be remembered that this is a biological system much more akin to domestic animals than to power generating stations. Just as it takes a farmer several years of experimentation to develop an efficient mode of operation (chores) with any type of livestock, so with the operation of this system. The pilot-scale system, now well into its third year of operation, shows a steady increase in production. There is every reason to believe that the same will occur with the Urbanic's system.

Section 10

System Components and Integration with Economic Analyses

In this section, the various components of Draco II will be described and analysed both independently and as they interrelate. Although the existing system includes only digesters, greenhouse and algea/aquatic plant ponds, this account includes the potential for incorporating a pisciculture (fish) pond and fuel alcohol still. This has been done to give a better idea of the potential for these types of systems.

Section 10A-1

Greenhouse

The greenhouse in this system covers 40 ft. of the south wall of the digesters. Reinforced concrete footers and reinforced concrete block form the foundation to which 2"x8" rough-cut oak plates were bolted. A 30" knee wall includes five 28"x76", double glazed sections of which three open for ventilation. Doubled 76" tempered safety was also used for the 450 slope which covers the length of the greenhouse. The slightly sloping 6' roof has an R value of 18.6 and includes three 6"x8' vents next to the digester. End walls are 2"x4" frame and sided with rough-cut oak lumber. The R value of both walls and the site-built doors is 11.94. The floor is dirt.

Floor space amounts to 418 ft.^{3} charging 15% of concrete and block work to the greenhouse gives a cost of about \$20.00/ft.^{2}. While this is on the higher side of greenhouse capital costs (53,122,222) the durability of this greenhouse should easily justify this initial cost. Also, the 10' height allows for at least three tiers of 2' wide racks for sprouting and small plants. This will add about 200 ft.^{2} of growing space which would be used primarily in the spring for seedlings.

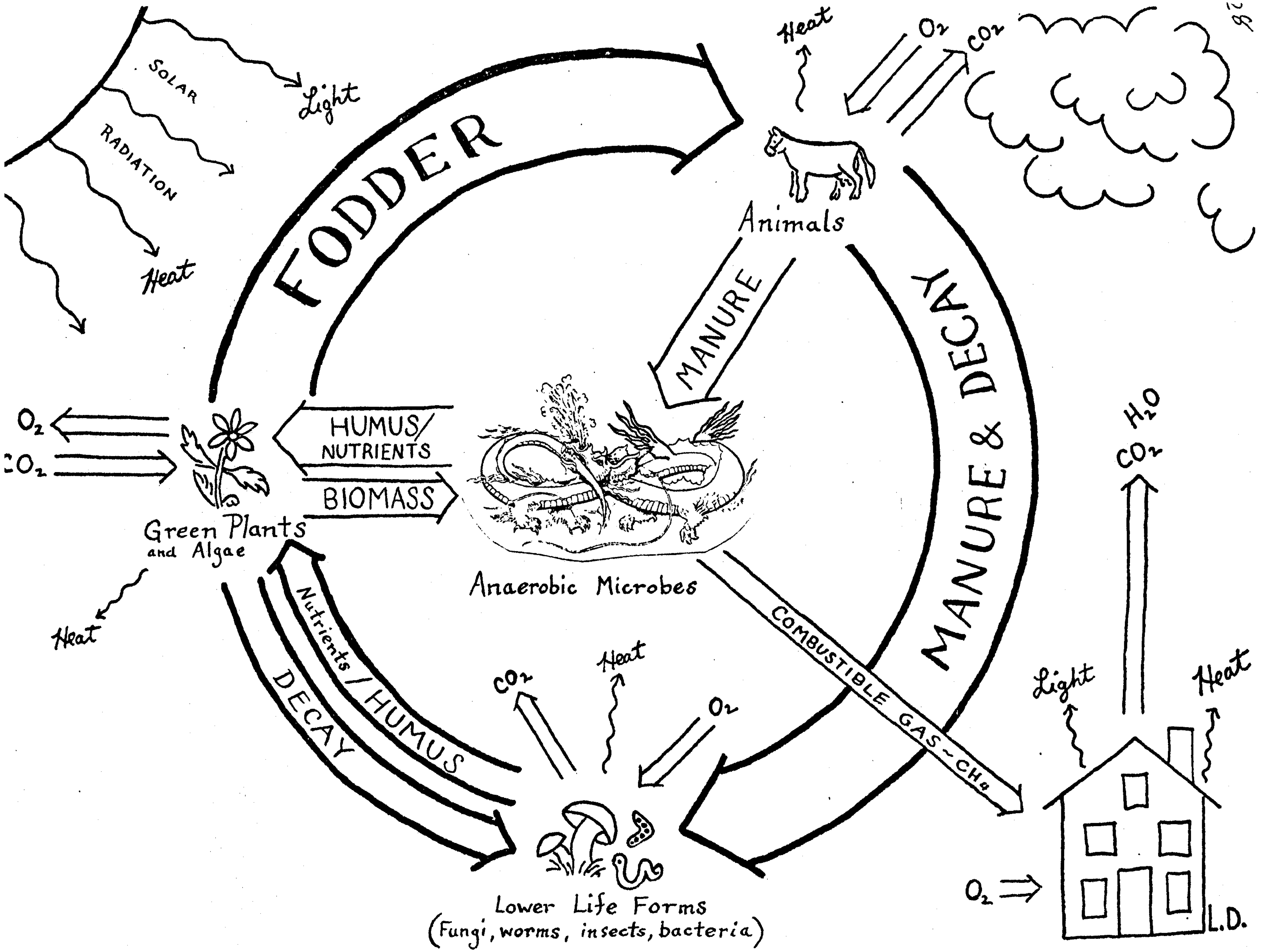
A typical commercial tomato greenhouse will produce 110tons/acre through the labor of 2.5 persons. This amounts to 15-20 times the best field production. (186) Unfortunately, this rate of production requires 100 times more fuel oil/ton of tomatoes than field production. To maintain a temperature of 55-65°F requires about 240x10 BTU/yr./ft.^{2} of growing space in the northeastern United States (163,186). More will be said about greenhouse energy requirements in the section dealing with digester/ greenhouse integration.

Attached solar greenhouses of about 200 ft.^{2} are calculated to provide vegetables, (≈410 lb.) seedlings, and ornamentals worth \$250-\$565/year (1977 and 1979 dollars). (53,222). Commercial greenhouses have been valued at \$4-\$5/ft.^{3} when full heating is required. (217) Several years of work and experience will be required before anything near optimum production can be approached. With all this in mind, for the purposes of monetary analysis, a value of \$4/ft.^{2} of floor space per year, and ½ hr. of labor per day (at \$3/hr.) will be used.

Effects of Greenhouse (See also Sections 11-15)

Individual-Financial:

food, seedlings and ornamentals-	$1672/yr.
labor-½ hr./day-	$ 548/yr.
outside labor saved-@$5/hr.-	333.4 hr.


SOLAR
RADIATION
Light
Heat
FODDER
Heat
O_2
CO_2
Animals
MANURE
MANURE & DECAY
O_2
CO_2
HUMUS/
NUTRIENTS
BIOMASS
Green Plants
and Algae
Heat
Anaerobic Microbes
H_2O
CO_2
COMBUSTIBLE GAS~CH_4
Nutrients / HUMUS
DECAY
CO_2
Heat
O_2
Light
Heat
O_2
Lower Life Forms
(Fungi, worms, insects, bacteria)
L.D.

Section 10B-1

Digesters

The anaerobic decomposition of organic materials is a naturally occuring bacterial process in stagnant ponds, in the intestines of large animals, and in other niches where free oxygen is excluded. The illustration opposite shows the process' position in the workings of the biosphere. For an introduction to the process and its applications I suggest References 96-House (especially) 72-Fry and 138-Merrill for brief introductions, and 48-Crook and 135-McGarry for Chinese systems.

Rather than reviewing the entire process, I will offer following general thoughts which have provided the basis for the approach used in this project. It should always be kept in mind that a digester is basically another 'ruminant' step in the food chain. Its food is the organic waste of others and it provides an easily usable form of energy and a more decomposed and stabilized "manure" for land use.

The primary requirement for digestion is a water and gas tight tank. The next major requirement regards temperature. The highest rate of gas production occurs at around 98°F (excluding thermophilic digesters which are not appropriate to low-technology application). However the process continues at a decreasing rate down to below 50°F (at which the Chinese still clain to get adequate gas production). Maintaining a digester at optimum temperatures can require from $\frac{1}{4}$ to $\frac{1}{2}$ the gas production. Larger digesters with a longer retention time and lower operating temperatures get the same total gas production (and perhaps higher net yield) as do smaller, high temperature systems. Once digestion is established it's stability or gradual change which is most important. A 75°F digester which rises say, 5°F in 24 hours would drop its gas production for several days until the 'beast' reaclimated itself.

In most low technology situations, if tank and temperature are taken care of, then the other parameters allow a great leeway. Actually much confusion about digestion is generated by the profusion of examined parameters and the units in which they are reported. The pH will naturally approach optimum (for any specific digester feed) unless the system is being overloaded in which case bicarbonate of soda brings relief. (55) The carbon/nitrogen ratio is relevant but it is digestible C and N which count and no tests currently give these figures. Stable digesters have been operated on feed with a C/N ratio as low as 5/1 but 20/1 to 30/1 is a reasonable figure at which to aim. Solid contents of successful digesters have varied from 2% in some municipal treatment plants to 48% in a batch system. (11) This depends mostly on whether the digester is batch, continuous, or something in between as exemplified by Draco II. Some agitation is helpful but not necessary, and occasional is preferable to constant mixing. The build-up of ammonia and salt concentrations can cause problems but all is not known about these areas. Very stable digesters have operated at ammonia concentrations several times higher than that which "the literature" claimed to be maximum. (240)

For constant gas production, two smaller digesters are superior to one large one. Even the best of digesters will 'get sick' or require cleaning occasionally. The additional cost of two smaller tanks is negligible considering the security and flexibility they afford.

In a smaller-scale situation (say less than 100 dairy cows) it is difficult, if not impossible, to justify digestion on the basis of the gas alone. However, with the possibilities for integrated systems, such as the system in thisproject, digestion becomes the basis for other production systems and the biogas is reduced to a by-product.

In so far as this system is concerned, the digesters will be fed (via human labor) by the manure and bedding from 5-8 horses, 1-3 milk cows, 20-50 chickens, 3-50 rabbits, 20-50 sheep and kitchen wastes of a family of five. Total weight of dry solids from these sources will amount to about 30 tons/year of which about 15 tons will be fed to the digesters. At 5 ft.^{3} of methane per pound of dry organic material, (8) biogas production would be equivalent to 150,000 ft.^{3} natural gas per year. (assuming CH_4 content of 60%). For this and other small-scale situations, direct burning of thegas is the only practical means of utilization (overall efficiency of biogas to electricity conversion is about 14.5%. (131)). The biogas will be used to replace natural gas for cooking, canning, water heating/refrigeration and greenhouse and house heating. While the biogas will not meet all of these requirements, it will replace the need to purchase 150MCF of natural gas. Natural gas currently sells [illegible] value of about $625 /year.

TABLE 12 Corn Dry Matter Yields on Withee Silt Loam Soil (57)

Manure Treatment	Yield	% recovery by corn N	P	K
fresh	19.5	44.0	19.5	40.5
fermented	19.5	42.0	22.5	49.5
aerobic liquid	17.0	18.5	19.5	38.0
anaerobic liquid	22.5	52.5	29.0	48.0

TABLE 13 (68)

Energy Installation	Energy Prod. 10^9BTU/day	Water Req. 10^6gal/day	Water Req. gal/10^6BTU
1000 MW coal fired plant	61.4	10.3	170
1000 MW nuclear plant (LWR)	61.4	17.3	280
250 MCF coal gasification	236	28	120
100,000 brl/day coal liquifaction	580	18	31
100,000 brl/day oil shale	580	18	28
Biogas digesters*			68*

TABLE 14

Disease Organism	Retention Time	Reduction in Viable Organisms	Reduction in Viability	Ref.
Schistosome Eggs (winter)	37 days	100%		(48)
Schistosome Eggs (summer)	14 days	100%		(48)
Hookworm Eggs	30 days	100%		(48)
Flat/tape worm Eggs	70 days	99% (over)		(48)
Dysentery Bacillus	30 hr.	100%		(48)
Paratyphoid Bacillus	44 days	100%		(48)
Average # of Parasite Eggs	?	93.6%		(135)
Ascarid Eggs	?	61%		(135)
Spirochetes	31 hr.	100%		(135)
E. Coli	?	99.94%		(135)
Salmonella Spp.	2-20 days 22-37°C	82-96%		(13)
Salmonella Typhosa	2-20 days 22-37°C	99%		(13)
Myobacterium Tuberculosis	? 30 C	100%		(13)
Oscaris Lumbricoide	15 29 C	90		(13)
Poliovirus-1	2 35 C	98.5%		(13)

*added for this paper

(Also consider that natural gas prices are projected to triple in the next 10 years.)

Oak firewood has a heat value of about $26x10^6$ BTU/cord (185) and requires 3.34 man-hours of labor, excluding splitting (84)(an extremely low figure compared to local experience) fire lighting and stoking, cleaning, etc-say 6 man-hours/cord. It is expected that two cords of wood will be replaced by 1/3 of the biogas each year. This wood will be left in the forests to decompose into humus.

Just as with the other domestic animals, digesters often require watering as well as feeding. This water is necessary to obtain anaerobic conditions and the circulation of materials within the tank. Digester water requirements of other energy sources in Table 13. The 68 gal. figure for digestion is certainly a maximum since amny digesters function well on fresh manure and urine alone. It must also be noted that digester water becomes a nutrient solution for irrigation rather than a pollution problem as in other installations.

The centralized energy sources now exploited result in numerous negative environmental impacts which would be avoided by extensive employment of systems similar to that in this project. Those impacts include; a) increase in atmospheric CO2 and heat levels (61) b)the environmental degradation caused by enrgy extraction (for example strip mining of coal directly disturbs 153,000 acres/year, indirectly affects 3-5 times that area and pollutes 12,000 miles of streams with acids and erosion (160)) and c) degradation caused by energy transport (for example, for every million tons of petroleum transported around the world 960 tons end up in the oceans (68).

In a local context (personal observations in central West Virginia) natural gas exploitation results yearly in hundreds of thousands of dollars worth of road destruction. This in turn leads to significant yearly expenses in personal vehicle upkeep.

While anaerobic digestion is attractive for the biogas, its service as an environmentally sound waste handling method is at least as important. Tables 7, 8, 9, (Jewell, et. al. 103), 10 (Miner, 141), and 11 (Kraft, 115) pp 32-35 compare numerous alternatives for farm waste handling and show that systems including digestion ("fermentation") seem quite competitive even when considering only the benefits of energy and primary plant nutrients (Nitrogen, Phosphorus and Potassium).

[illegible] about 136 million dry tons of livestock manure produced

TABLE 7 Net Annual Cost of Waste Handling Schemes Not Employing Anaerobic Fermentation For a 100 Cow Dairy Farm. (103)

System Components	System No.	Operating Cost	Fertilizer Value	Net System Cost
gutter cleaner-solid spreader	2	$10,789.	$ 5,101.	$ 5,697.
alley scraper-piston pump-earthen storage-injection (land)	11	11,007.	7,071	3,936.
alley scraper-piston pump-earthen storage-liquid spreader	12	10,723.	6,364.	4,359.
alley scraper-solid spreader	16	8,278.	5,555.	2,723.
tractor scraper-stack-solid spreader	17	7,295.	5,000.	2,925.
tractor scraper-solid spreader	18	6,771.	5,202.	1,569.
tractor scraper-piston pump-earthen storage-injection	19	9,985.	7,071.	2,914.
tractor scraper-piston pump-earthen storage-liquid spreader	20	9,701.	6,364.	3,337.

TABLE 8. Net Annual Cost of Waste Handling Schemes Employing Treatment Systems (Excluding Anaerobic Fermentation) For a 100 Cow Dairy Farm. (103)

System Components	System No.	Operating Cost	Fertilizer Value	Net System Cost
alley scraper-licom storage-injection	10	$18,999.	$ 7,274.	$11,725.
alley scraper-piston pump-anaerobic lagoon-injection	13	15,652.	7,173.	8,479.
slotted floor-oxidation ditch-storage-liquid spreader	26	15,124.	5,050.	10,074.
slotted floor-dry ditch-solid spreader	27	14,338.	4,798.	8,540.
alley flush-collection sump-anaerobic lagoon-aerobic lagoon-irrigation	32	15,146.	4,040.	11,106.

TABLE 9. Net Annual Cost of Waste Handling Systems Employing Anaerobic Fermentation For a 100 Cow Dairy Farm Taking $5.00/MMBTU Credit on Biogas Generated (103)

System Components	Reactor Type	System No.	Tot. Oper. Cost	Fertilizer Value	Value of Net Methane Production	Net. System Cost
gutter cleaner-fermentor	plug flow	36	$12,077.	$ 4,747.	$ 4,952.	$ 2,378.
earthen storage-irrigation	conventional		13,301.	4,747.	5,708.	2,846.
alley scraper-fermentor	plug flow	37	13,357.	4,747.	4,952.	3,658.
earthen storage-liquid spreader	conventional		14,581.	4,747.	5,708.	4,126.
alley scraper-fermentor	plug flow	38	13,640.	7,173.	4,952.	464.
earthen storage-injection	conventional		14,864.	7,173.	5,708.	1,983.
tractor scraper-fermentor	plug flow	40	12,306.	4,747.	4,952.	2,607.
earthen storage-liquid spreader	conventional		13,530.	4,747.	5,708.	3,075.
tractor scraper-fermentor	plug flow	41	12,589.	7,173.	4,952.	464.
earthen storage-injection	conventional		13,813.	7,173.	5,708.	932.
flush-fermentor-earthen storage-injection	plug flow	44	12,076.	7,173.	4,952.	-49.
	conventional		13,330.	7,173.	5,708.	419.
flush-fermentor-earthen storage-irrigation	plug flow	45	10,449.	4,747.	4,952.	750.
	conventional		11,673.	4,747.	5,708.	1,218.

TABLE 10 Tentative Method of Evaluation of Four Methods of Handling Manure on an "Average" Dairy Farm in Southeastern Wisconson. (141)

items of comparison	relative value for type of manure a) (no. 1=most favorable) b) fresh	fermented	aerobic liquid	anaerobic liquid
effect on corn yeild	2	1	4	1
effect on nutrient recovery	3	1	4	2
effect on labor:				
seasonable distribution	1	3	3	3 [?]
total required	2	2	1	1
flexibility in:				
time of application	3	1	1	1
method of application	3	3	1	1
amount of bedding needed	2	2	1	1
possibility for least pollution of:				
lakes and streams	3	2	1	1
air	1	3	2	4 [?]
relative investment cost	1	2	4	3
Total	21	20	22	18

a) It is assumed that fresh manure generally would be spread daily as produced and that the fermented and aerobic liquid manures (optimum storage) would be applied when conditions were suitable and that the manure would be incorporated into the soil before much drying had occurred.

b) A difference of more than one unit between relative values suggests important or statistically significant differences between items of comparison.

TABLE 11 Annual Costs and Revenues of Selected Manure Handling Systems. (115)

costs	digester and lagoon	anaerobic lagoon	in barn storage	oxidation ditch and lagoon
barn	$ 947.	$ 961.	$ 4,039.	$ 2,969.
equipment and labor	2,793.	-	-	767.
lagoon	192.	416.	-	267.
spreading manure	602.	2,202.	1.117.	2,070.
electricity	.65	-	-	947.
total	$ 4.599.	$ 3,579.	$ 5,156.	$ 7,020.
revenues				
fertilizer	$ 1,888.	$ 2,005.	$ 2,699.	$ 1,888.
gas for heating	1,364.	-	-	-
total	$ 3,252.	$ 1,574.	$ 2,457.	$ 5.133.
net costs	$ 1.347.	$ 1,574.	$ 2,457.	$ 5,133.

yearly in the U.S..(184) Manure produced in unconfined situations is generally distributed broadly enough that natural aerobic decompositon is adequate for its break-down and recycling. The concentration of manure produced in confined situations, about 60% of the total (184) is a great threat to the health and productivity of local bodies of water.

Too much unstabilized organic matter entering a body of water will cause increased algae growth which uses up dissolved oxygen. These uncontrolled anaerobic conditions are detrimental to fish and other aerobic life forms associated with fresh bodies of water. Controlled anaerobic digestion of manures at the site of production would certainly be more expiditious.

Digestion results in 60-90% stabilization of the total biodegradable solids, depending on digester desogn, temperature and retention time. (105, 106, 207) The odor of digester effluent is very significantly reduced (210) and flies and rodents are not attracted to it. (57)

The strongest negative factor in the use of human and animal manures as fertilizer for production of food and feed is the possibility od disease transmission. (67) Table 14 shows that the anaerobic environment within a digester is of great assistance in limiting that possibility. These figures must be compared with the total pathogen destruction offered by composting. That total destruction is obtained, however, only by regular turning or aeration so that all material reaches nearly 140°F. (76)

It is also worth noting that the factors favoring survival of normal soil bacteria tend to favor destruction of pathogens. (143) This gives added importance to what is organic farming's most basic tenet-that the soil is a living, breathing supra-organism which must be cared for and fed, rather than poisoned, and that the health of humans and other animals is dependent on the health of the soil. (169)

Organic farming is being increasingly recognized to be quite competitive financially with conventional farming. (123, 169, 205) Actually the term "conventional farming" as it is used today to denote the methods including extensive use of chemical fertilizers, fungicides and pesticides is a mis-nomer applied by its advocates to give credence to a system which has really only developed over the last 40 years. Organic farming is far more truly conventional/traditional.

Perelman notes that early research on hybrid corn stressed:

> "the increases in quantity of corn produced by hybrid seeds...[while not mentioning] that the quality of the corn was reduced and that the new seeds necessitated massive increases in specialized inputs such as chemical fertilizer. Thus while the new technology did give a farm more returns for a given cost of production, it did NOT give produce of the same output with the same inputs; but rather different amounts of different outputs for different amounts of different inputs in the same sense as if the farm had been converted into a golf course or a factory for producing tennis rackets." (151)

He also points out that, while credit for high "Green Revolution" yields always go to hybrid seeds and chemical fertilizer and pesticides, the favorable weather has played a major role (up to 50% in one study) in the increased yields over the past several decades. (151) Animals comprise an essential part of operation of organic farms since their manure is highly valued as fertilizer and soil amandment. Thus the system described here fits in quite well with the principles and practices of organic farming.

The fertilizer and soil amandment value of digester effluent is subject to wide disagreement among researchers. Pimental claims that while digested manure retains the original nutrients ite particle size has been reduced so far that land application cannot maintain soil structure or prevent erosion. (154) On the other hand, Coppinger, et. al. claim that well digested manure drains and dries more quickly and therefore reduces run-off. (57) I am quite sure that the bedding and lage-particle fed to the Draco II digesters will certainly provide a large enough particle size to improve soil structure.

Quantification of the beneficial effects of the organic component of manures has not been satisfactorily accomplished. (205) One point noted by Robert, et. al.(169) is that organic farmers in the western corn belt could use at least one higher gear on heavy tractor operations after several years of organic farming. (169) (U.S. farm output per horsepower of tractors fell by about 31% between 1950 and 1970. (151)) Thus if digester effluent were applied to fields which had been recieving only chemical fertilizer, there would be savings of about 5% in some crop operations. In the case of Draco II the manure was spread previously so that no credit can be taken on this point.

There is also some disagreement as to the comparative value of digester effluent as a source for primary plant nutrients-nitrogen (N) phosphorus (P) and potassium (K). This is largely due to the digestion process converting a portion of manure's organic nitrogen to ammonia which, although more easily used by plants, is also more easily evaporated. (111) The problem of ammonia evaporation can be controlled by injection or plowdown with the benefits of lower nutrient loss offsetting the costs of incorporation. (212)

Effect on crop yield would be the ideal method for quantifying the value of digester effluent. Several years are required for development of any such reliable data. Table 12 (p31) shows that anaerobic effluent tields the greatest recycling of nutrients of the treatments considered.

The Chinese would seem to have the most extensive experience with digester effluent. Regardless of the method of application, increased crop yields as a result of effluent use were always reported-10-13% at most communes. (40) Earlier reports claimed increases of 28% for corn, 10% for rice, 25.7% for wheat. (48) In these analyses a value of 10% increased yield over undigested manure will be used for quantification.

An alternative to returning manure or digested sludge to the soil is to dry and refeed the solids. This is based on the nutrients in dry manure being worth $83-100/ton as feedstuff. (132) Digested, centrifuged sludge is 18-23% organic nitrogen with an amino acid analysis that compares favorably with soybeans. (87) But in feeding trials there have been palatability problems. (132)

The following Sections offer other alternatives for utilization of digester effluent.

<u>Digester Values</u>

Individual-Financial:

Gas heat value (when natural gas = 4.50/MCF)	=	$675/yr.
Increased crop growth on digester effluent 5 acres/year, 10 tons/acre on corn	=	$154/yr.
Fertilizer replaced valued at $.15/lb.N, $.40/lb. P, $.10/lb.K (205)	=	$ 25/yr.
odor and fly reduction and health improvement	=	++
Labor for one extra manure handling. 1 wk.@ $3/hr.	=	$210/yr.

Humus value of timber saved	=	++
Firewood labor saved	=	12 hr./yr.
Outside labor saved	=	135 hr./yr.
Some % of Societal Benefits	=	++

Societal-Economic:

No effect on atmospheric CO2 and heat levels	= Some % of the value of land which would be inundated by melting of polar ice caps.
Reduced pollution and destruction of land and water ecosystems	= Some % of the value of increased food (pleasure and contentment) harvested from those ecosystems
Reduced expenditures for road maintenance	= Some % of local and State taxes and auto repairs

Section 10C-1

Greenhouse/Digester Integration

There are several symbiotic pathways through which greenhouse and digester relate. These include heat transfer both ways, CO_2 enrichment of the greenhouse through combustion of biogas, and digested liquid fertilizer for plants. Employing a digester as thermal mass in a solar greenhouse gives the advantage of increased utilization of the volume occupied by that mass. Instead of just being there, the digester provides useful by-products. The problem with a greenhouse enclosed digester is that the digester and gas lines are bound to leak sometime, and explosive concentrations could develop. The side-by-side orientation and venting in this unit negates that possibility.

In this system, mass of the digester includes about 56 tons of slurry (varying from about 2 to 15% solids) about 130 tons of block, concrete, etc., and 2 tons of rock in the thermosiphon system. Heat is transferred directly through the 320 $ft.^2$ of common block wall which was filled with concrete and rebar or gravel. Loose figures (after ref. 230) show that heat transfer would be about 480 BTU/hr. for each difference of 1°F between the digester and greenhouse. Thus the digester acts as a source for both heating and cooling. Experience with the pilot-scale system can be used to evaluate these benefits. During spring and summer, digester temperatures rose from 55°F to 80°F. For Draco II this would be equivalent to an input of about 4.2×10^6 BTU/year ($\approx$4200 $ft.^3$ methane) to the digester. When digester heat losses are included, this transfer would amount to an even greater cooling influence on the greenhouse, but due to the complexity of computation this effect will not be quantified. Much of the heat absorbed by the digester is returned to the greenhouse in cold weather so that the BTU benefits are doubled. (Day-to-day analysis of this interaction would certainly lead to a much higher figure.)

Plants require CO_2 levels of 330 ppm (ambient) or above. Commercial vegetable and rose growers like to maintain a level of 100-1500 ppm which requires about 75 lb.CO_2/acre/hr.. A greenhouse's CO_2 levels can drop to 200 ppm in 20 minutes on a sunny day and the greenhouse in Draco II is quite tight so that CO_2 supplementation is suggested during winter when ventilation is not practical. Biogas is about 40% CO_2 and complete combustion of the 60% which is methane produces a nearly equal cubic footage of CO_2 and water vapor-an ideal situation for a greenhouse. CO_2 costs $16.00 for 244 ft.³ 10% of the total biogas production (~210,000 ft.³) in the greenhouse, would supply 21,000 ft.³ of CO_2 worth $1377./yr.

The fertilizer value of digester effluent was discussed in Section 10-B. Again taking the Chinese figures of 10-15% increased yield, the effluent should result in an additional $167. worth of production from the greenhouse.

Effects of Greenhouse/Digester Integration (See also Sections 11-15)

Individual-Financial:

8400 ft.³ natural gas equivalent at $4.50/MCF	=$ 38.00/yr.
greenhouse cooling by digester	= ++
21,000 ft. CO_2 to greenhouse	=$1377./yr.
increased growth on effluent	=$ 167./yr.
outside labor saved (@ $5./hr.)	= 316.4/hr.

TABLE 15 Mean Water Quality of Two NASA Experimental Systems at Existing Domestic Waste Treatment Lagoon Systems in Southern Mississippi. (218)

Location	Without Water Hyacinth				With Water Hyacinth			
	BOD5-ppm		TSS-ppm		BOD5-ppm		TSS-ppm	
	influent	effluent	influent	effluent	inf.	eff.	inf.	eff.
Lacedale	127	52	140	77	151	23	125	6
NSTL Lagoon #1	91	17	79	49	110	5	97	10

Section 10D-1

Algae/Aquatic Plant Ponds

While Digester liquid can be used effectively to irrigate field crops, its high nutrient content makes it ideal for the growing of various aquatic plants and algae. The are two considerations for determining the worth of such a flow: the value of waste stabilization and the value of pond production.

The aquatic plants most often considered for waste stabilization lagoons are water hyacinth, Eichlornia crassipes, and duckweeds, the simplest of flowering plants (95) which include Lamna sp., Spirodela sp., and Wolffia sp., all of which thrive in nutrient rich waters.(218) Henderson, et al, concluded that when the ability to reduce suspended solids and BOD5 was considered, aquaculture strategies were always more cost effective than conventional alternatives.(93)

In areas where water conservation is important, duckweed is useful in lowering evaporation. (172) Duckweed growth provides favorable conditions for growth of Daphnia and other microscopic metazoa that contribute to water purification by devouring bacteria and algae cells.

Water hyacinth is a warm weather plant which can increase evaporation rate by 2-7 times.(202) It has a doubling time of 10 days and shows weight gains of 4.8%/day in good conditions. (209) At a production rate of 44.6 dry tons/acre year (over 79 dry tons/acre year has been recorded (219)) water hyacinth would remove all the nitrogen from a typical wastewater flow of 66,000 gal/day.(19) Fecal Coliform is also significantly reduced, probably because the growth of bacteria feeding organisms is enouraged. (209) Table 15 shows the effect of water hyacinth growth on municipal sewage.

Duckweed grown in waste lagoons has a crude protein content of 32-44%.(95) Where most crops average about 1 ton/acre/year, and corn (with residues) averages 5 ton/acre/year, (207) duckweed has produced from (95) to 10 (49) tons/acre/year. It has few pests so that control is negligible compared to traditional crops. (49) It can take the light freezes and is harvestable by skimming. In feeding trials, when replacing alfalfa in chicken feed, growth increased (49); cows were found to accept up to 75% (total dry weight) with no ill effects. (95) (There is a toxic blue-green algae which may grow on waste lagoons after duckweed harvest but this danger is avoided by "processing".(49))

Water hyacinth has demonstrated yeilds of 154 dry tons/acre in a 7 month growing season (207) with crude protein content of around 23%. (60) Ensiled at 15% moisture, it is palatable to large domestic animals at up to 20% in meal or pellets without mineral imbalances, (209)

Draco II's ponds cover about 600 sq. ft. which is not really large enough to make a significant contribution to feed needs when growing aquatic plants. Duckweed production equivalent to 10 ton/acre/year would yeild about 300 lb. which would displace only $40. worth of soybean meal.

Mosquito problems are likely to develop in the various pond sections. In the stronger sections a fiberglass screen should solve the problem. In the production sections, duckweed growth can be thick enough to keep larva from the surface (49) and the mosquito fish, Gambusia offinis, may be introduced.

The production of algae in unsterile outdoor conditions is no more complex than producing vegetable crops. (148) Chlorella, a unicellular green algae, requires 1/10th the land, 1/5th the water, 3/4 the power, 1/15th the labor, and 1/4 the capital of conventional agriculture for an equal amount of protein. (148) Chlorella and other indigenous algae have grown on domestic sewage at visible light conversion efficiencies of 4-5% (146)-near the theoretical limits. Unfortunately this algae is difficult to harvest even in the most high-tech situation.

Spirulina is a helical blue-green algae (Class-Cyanophyceae, Order-Nostocales, Family-Oscillatoreaceace)(208) which contains 70% protein, 8% fats, 16% carbohydrates, and has an aminogram comparable to egg protein. (183) In feeding trials on rats, hens, piglets, calves, fish and humans, Spirulina has demonstrated a high nutritive value and no toxicity. (183) The cell walls are mucopolymer and lipopolysaccharide making assimilation easier than the cellulose of greens. Only minor agitation is necessary because Spirulina have gas vacuoles which allow migration to zones of optimum sunlight and mass transfer. (181) The helical shape causes clumping. (208) In a turbid solution (like diluted digester supernatant) early morning accumulation at the surface allows for harvesting with a fine gauze screen

Algae show great tolerance of trace element concentrations as long as macronutrient levels are adequate. Digester effluent has been shown to meet these requirements. (35) Spirulina productionlevels have reached 86.8 lb./acre/day on digested swine manure.(204) In India a five-cow family using digestion could grow 92.6 lb. of Spirulina/300 day season on one 490 sq. ft., 1 ft. deep pond. (170) (See also Section 10E.)

Algae/Aquatic Plant Pond Effects (See also Sections 11-15)

Individual-Financial:

Feed Production-300 lb. of 40% protein @ $13./100lb. (based on duckweed, the simplest but probably least productive alternative for pond use) = $40./yr.

Labor Required-30 hr. @ $3./hr. = $117/yr.

Outside Labor Saved @ $5./hr. = 8 hr.

Societal-Economic:

Decreased pollution of water resources-leading to better health and greater harvests.

Section 10E-1

Algae/Aquatic Plant Digester Integration

Evaluation of digester/algae and aqutic plant pond integration must include valuation of the total waste stabilization obtained, the value of digester supernatant as a medium for growth, and the value of digestion of pond growth.

Digester effluent after flowing through Chlorella anf Spirulina ponds, was found to meet New Mexico Environmental Improvement Agency water standards. (35) The algae effluent contained 50-85% less total dissolved solids than the digester effluent. (35) As stated in Section 10D digester effluent provides an excellent substrate for spirulina growth. (35,244) In work done in India, Spirulina growth on a chemical cultural medium (Zarrouk's Medium) was compared to growth on an original medium of 1/2 Zarrouk's Medium plus 5% volume/volume of biogas effluent per day. Yield was about 25% higher and chemical costs were about 85% less with the effluent. (170)

Algae's small size makes it an excellent digester feed. The addition of 30% algal total volatile solids has increased biogas production by 17%. (224) Chlorella grown on sewage can be digested with 65% efficiency in bioconversion of energy. (146) Digestion of Chlorella production of 20 tons/acre/year would yield a net energy production of 200×10^6 BTU/acre/year. (21)

The high moisture, high nutrient, and low lignocellulose content of most aquatic plants make them ideal for digestion. (19) Water hyacinth digestion gives an average bioconversion efficiency of 47%. (172) At water hyacinth production rates of 64/tons/acre/year, digestion would provide 476×10^6 BTU/acre/year.(218) Water hyacinth grown on digested water hyacinth liquid and solids gave 65% and 47% higher yields than that grown on a chemically defined medium.

Effects of Digester/Algae and Aquatic Plant Pond Integration (See also Sections 11-15)

Individual-Financial:

If pollution control regulations must be met, nearly the entire cost can be credited to the digester/pond integration = $\$x \times 10^{3 \text{ to } 5}$

-When considering the duckweed alternative, integrative = value is duckweed production

-When considering water hyacinth alternative integrative value is increased gas production etc. (See section 10B)

-When considering Spirulina alternative integrative value lies in Spirulina production, $ saved on chemical culture medium, and outside labor saved.

-Some % of Societal Benefits

Societal-Economic:

Decreased pollution of water resources leading to better health and greater harvests.

TABLE 16 Typical Polyculture (93)

Food Habit	Production maximum lb./acre/year	Example species
plankton feeder	350	Golden Shiner
benthos feeder	1375	Channel Catfish
detritus feeder	1350	Goldfish
Specialized Types		
zooplankton	470	Bigmouth Buffalo
predator	50	Largemouth Bass
insectivore	100	Bluegill
Total	3695	

The mosquito fish, Gambusia offinis, can be added to control mosquito larvae.

Section 10F-1

Fish Pond

As ocean and fresh water fish yields continue to fall due to over-harvest and pollution, fish farming becomes increasingly attractive. Productive units can range from New Alchemy's 630 gal. Solar-Algae Pond tanks, through back yard ponds, up to several acre commercial operations.

Monoculture catfish farming in the U.S. yields 1786 lb./acre/year. (67) Polyculture farming as practiced in many Asian countries can yield 4465-7144 lb./acre/year. (67) Polyculture takes advantage of the selective feeding niches of a variety of fish to more effectively utilize all regions of the pond. Table 16 gives an example.

In Asia manures are often used to provide fish nutrients. Pullin, et al (165) found that fish growth, equivalent to that on conventional feed, was obtained with pellets comprised of up to 30% dry manure. In the same study, manure added directly to the pond was found to stimulate heterotropic growth which provided minerals and CO2 for autotropic (photosynthetic) growth. Heterotropic growth accounted for about 1/2 the fish yield via pathways such as tilapia or silver carp obtaining nutrients from the microbial community in detritus followed by recolonization of the detritus passing through those fish. (165)

Manure and night soil feeding of fish can cause health problems because some flat-worms (liver infections) have fish as as intermediate host and because fish may aquire a large number of enteric bacteria on their bodies and within their intestines. (67) This concern must be tempered somewhat because a bacterial evaluation of 200 samples of raw frozen marine fish packed for sale showed fecal streptococci in 53%, fecal coliform in 16%, and E. coli in 10%. (165) The appropriate conclusion then, is that one should cook all fish.

A 1/2 to 3/4 acre fish pond will ultimately be constructed about 500 ft. from the basic digester/greenhouse/algae and aquatic plant pond unit in this project. Production will depend upon the owners' efforts and is very difficult to estimate at this time. Some form of non-intensive polyculture can be anticipated, but production will depend on the owners' efforts and is difficult to judge at this time. Below are some (hopefully) reasonable guesstimates.

Effects of Fish Pond (See also Sections 11-15)

Individual-Financial:

Fish harvest 500 lb./year @ $.50 lb. = $750./year

Expenses to stock pond = $200./year

Labor (/) for harvest = 110 hr.

Fish Pond/System Integration

Pathways of integration between the fish pond and the rest of the system are more limited than the pathways discussed previously. Manure can be fed directly to the pond for feed but the potential biogas would be lost. I have seen no reports of investigations of digester effluent as fish feed but yields equal to those with manure feeding can be expected.

Additional digester feed would be obtained when pond detritus is removed but this would be only occasional. The pond would be stocked with aquatic weeds but these would be better utilized by appropriate stocking of herbivorous fish rather than harvesting for digestion. Any large excess could be used for gas production, but would be better used as livestock feed.

Water hyacinth and duckweed grown in the digester fed ponds could be fed to fish, (10) but would be more valuable added to livestock ration. Spirulina has been substituted for up to 50% of fish meals with good results (204) but this too would be more valuable to livestock.

Effects of Fish Pond/System Integration (See also Sections 11-15)

There is potential for integrated benefits in different or larger-scale situations, but in this instance direct effects are minimal.

Alcohol Production

Farm fuel alcohol production has largely been considered as a 10-20% additive to gasoline-gasohol. Gasohol can be utilized in standard vehicle engines but 200 proof (100%) anhydrous alcohol is required for the gas mixture.

Vehicles can be operated on pure alcohol with minor carburator adaptations and replacement of rubber and plastic gaskets which are deteriorated by the alcohol. After adaptation tractors run best on 160 proof alcohol with the same pulling power as with gasoline. (171) The distillation process for anhydrous alcohol requires an input of 108,000 BTU/gal. of ethanol. (176) One third of this energy is required to upgrade from 190 proof and if only 160 proof were required, then energy inputs would drop further. (37)

To realize the true value of farm alcohol, one must consider a farmer's plight when crops are ready for harvest and the gas tank is empty. When viewed in this light, a still is similar to crop insurance. (130) Chen, in one of the finest investigations of integrated systems I have seen, concluded that Illinois corn farmers could cover their entire mobile fuel needs by producing 160 proof alcohol from 1/11 of their 120 bu/acre crop. (37)

As with other systems there are problems with the overcentralization of alcohol production. Long distance transportation of feedstock and stillage is wasteful and can cut significantly into energy benefits. Also, for each gallon of alcohol, 16 gallons of water are needed for mash preparation, steam and cooking. (74) This can place a large burden on local supply. Thirdly, the quantities of stillage from a large plant with no means of proper utilization can pose a significant pollution problem. The stillage from a 20 mil.gal./year plant has a BOD5 load equal to the domestic waste from a city of a million people. (61)

Removal of plant residues normally left in the fields, for processing to alcohol is not advisable. Taking 4900 lb./acre of N, 4.9 lb. of P, 45 lb. of K, and 29 lb. of calcium (154) not to mention the erosion which would result.

As with biogas energy utilization, the utilization of alcohol fuel would not effect atmospheric CO_2 levels (except where fossil fuels were used for process heat) (See Section 10E.) (6)

Dry distillers grains vary from 25-30% protein. (176) Mature cattle can consume 7 lb. dry stillage per day which is about equal to the byproduct of one gallon of ethanol production. (74) The drying of distiller's grains can require up to 40% of distillery energy (64) so that local livestock consumption of the stillage would significantly limit energy requirements.

In regard to this project, there ultimately are plans for operation of a small still inside the greenhouse. Snall stills capable of 5-15 gal./day of 160-180 proof alcohol can be purchased for around $500. (192) For about $1000. worth of materials 70 hr. time, and some welding skills, one can make a still to provide 8-10 gal./hr. of 180 proof alcohol. (192) Since the average family requires about 100 gal./month, one day's efforts could provide the month's fuel from about 1 ton of corn. (192)

Since all biogas use has already been accounted for, quantification of alcohol production will not be attempted.

Effects of Alcohol Production (See also Sections 11-15)

Individual-Financial:

Still capitol costs & engine conversion-	-
Capitol investment & energy credits-	+
Feedstock costs-	-
Alcohol production-	+
Stillage feed benefits-	+
Operating labor costs-	-
Outside labor saved-	+
Security of supply-	+
Some % of societal benefits-	+

Societal-Economic:

Balance of payments-	+
Security-	+
Reduced environmental deterioration from fossil fuel exploitation-	+

TABLE 17 Calculations Based on 1 Acre of Corn Yield (33)

Energy required for ethanol production	14.1×10^6 BTU
Volume of biogas required	23,537 $ft.^3$
# of animals required for biogas	4.4 head of 800 lb. beef
# of cattle required for consumption of wet stillage	.28 head
Fertilizer value of sludge	
N	331 lb.
P	127 lb.
K	278 lb.
Land area that can be fertilized with sludge	
N	2.2 acres
P	4.5 acres
K	2 acres

TABLE 18 Energy-Inputs for Ethanol Production by Fermentation (37)

Operation	Commercial BTU/bushel	Farm BTU/bushel
corn production	130,000	130,000
cook and convert	36,000	biogas supplied
germ recovery	5,000	--
distilling	71,000	biogas supplied
gluten recovery	6,600	--
feed recovery (drying)	105,600	fed directly
electrical	9,500	9,500
Totals	324,300	139,500

Section 10I-1

Alcohol/System Integration

There are numerous benefits to be gained by the integration of small-scale alcohol production with a digester system. Over half of on-farm energy use is in the form of liquid fuels for transport and machinery. (35) A biogas powered still can be viewed as bioconversion of excess biogas energy into the more needed liquid. Since energy cost is the major operating expense for alcohol production, (31) the availability of"free"biogas limits that expense as well as the air pollution problem caused by using fossil fuels. The still's cooling water can be used to maintain or raise the digester's operating temperature.

Again drawing on Chen's excellent study, Table 17 shows an integrated farm's advantage in alcohol production. Chen's investigation of the animals necessary to produce adequate biogas, the animals necessary to consume the wet stillage within 24 hours, and the organic fertilizer which is provided by these animals. These calculations show that 15.7 times more livestock is required for biogas production than for stillage consumption. In such an integrated farm situation, this would probably mean that wet stillage would supplement the feed and water required for all livestock.

A different approach to digester/alcohol integration was taken by Shaeffer, et al. This system, quantified with U.S. totals in Table 18, includes electrical generation from biogas and alcohol production from engine waste heat. (184) The electricity produced could supply the average annual needs of 8% of America's housing units, the alcohol would didplace 65 million barrels of oil ($2,275 billion) and the fertilizer would displace 29 million barrels of oil ($1.015 billion). (184)

In regard to this project, alcohol/system integration, setting the still inside the greenhouse will be advantageous for heating and CO2 enrichment of the greenhouse and ease of circulation of still coolant through pipes placed in the base of the digesters. The quantification of the value of this integration will not be attempted.

Effects of Alcohol/System Integration (See also Sections 11-15)

Individual-Economic:

Reduced operating energy costs-	+
Increased greenhouse growth-	+
Increased digester temperatures-	+
Outside labor saved-	+
Security and independence of farm operations-	+
Some % of societal benfits-	+

Societal-Financial:

Balances of payments-	+
Security-	+
Reduced environmental deterioration from fossil fuel exploitation-	+

Local Production

Food, fuel and fertilizer systems in the U.S. have over the past four decades become extremely centralized. This has been to the agrandizement of a few areas (primarily the upper class suburban areas of a few large cities) but to the detriment of most other areas. Family farmers, still given lip service as "the backbone of the nation", are being financially broken at the rate of 2000 per week (the average since 1950 (120)) by economic policies instigated by agribusiness interests. Unemployed farm workers and rural craftsmen swell the more urban and industrial centers and "realities of the marketplace" devalue human labor and effort. "Scabs" are easy to find when one worker in every ten is looking for work.

Food processing and distribution has also "fallen into fewer and fewer hands over the past 30 years" (120) The former multitude of Mom and Pop groceries have been 'expatriated' by 3 or 4 supermarket chains. About 70% of all food processing profits went to less than .2% of the 32,000 processers still in business in 1975. (120) When adjusted for inflation, farmers received the same for commodities in 1971 as in 1948 so that the 35% rise in consumer prices were caused totally by higher marketing margins. (120) In 1978 the General Accounting Office reported that since 1973, 87% of the increased consumer expenditures for food was caused by higher food marketing charges. (120)

Energy corporations have competed and merged until a very few (if we were really honest) control a large part of our lives. Nearly free energy was pushed upon us until we were hooked. Now they are jacking up the price. (This is certainly more the work of corporate minds than that of individuals.) I suggest that the possibilities outlined in Section 10 offer an alternative and opportunity for redistribution.

determining a fair value to place on thelocal production of food and energy is somewhat (very) complex. The value of local goods in a local economy is only truly exposed when imports are cut off, (82) but every dollar earned by a family farmer is multiplied many times throughout the community. (214) Every dollar earned by an outside owner or passed on to an "outside" supplier is drained from the community.

Food in the U.S. averages 765 miles from producer to consumer. (97) Nearly ½ of highway trucking is food and agricultural related, (206) and food transport accounts for 1.46% of U.S. energy consumption. (196) One head of lettuce, being 95% water and

TABLE 19 Energy Required for Packaging Materials (153)

	BTU/lb.
paper	20,400
glass	7,628
steel	14,795
aluminum	98,316
plastics	18,544

New York. The energetics of the biosphere on which we depend can not provide for such absurdities.

Commercial canning of tomatoes consumes 1600/lb. fresh weight compared to home canning which by water bath for seven quarts requires 545 BTU/lb. canned. (97) Food processing consumes about 30% of the U.S. food system's energy. (100) Much of this energy is used for numerous expensive motions to remove various substances and then to readd them in a different form. (100)

Packaging currently takes 8-12% of the average food budget. (214) A 1 lb. can of corn embodying 269 kcal of food energy is contained in a can embodying 997 kcal. (29) Table 19 shows that glass, the conventional" hame canning material, is the least energy consumptive of packaging materials.

Organic fertilizer, largely locally produced and containing a full spectrum of plant nutrients have been largely displaced over the last 40 years by chemical fertilizers containing extremely high concentrations of primary plant nutrients. Chemical fertilizer production is energy intensive (especially for nitrogen) and requires elaborate centralized facilities. Average transportation distance is perhaps equal to that of food-765 miles. With organic farming and integrated recycling systems, the dollars now spent on chemical fertilizer purchases would remain in the local community.

The system described in this account provides for a significant increase in local production of food, fuel and fertilizer. This will result in a much lower requirement for outside income, and in the circulation of many dollars within the local community with a resultant invigorating effect. At least 1100 lb. of produce from the effluent enriched greenhouse will decrease food system transportation requirements by 1.05×10^6 BTU/yr. (1.25 BTU/lb.-mile x 1.100 lb. x 765 miles). The 10% increase in field and garden crops through effluent use is difficult to figure but, for sake of quantification an increase in corn production from 70 to 77 bu (70 lb./bu) on five acres would amount to another $.47 \times 10^6$ BTU/yr. decrease in transportation. All of this home production would limit the 30% of food system energy absorbed by commercial (over) processing. Five mile trips for groceries, requiring about 45,000 BTU (155) or about 3/5 gal. on gas, could be reduced.

Chemical fertilizers are not used on Urbanic's farm, but in a situation where they would be replaced by digester effluent there would be a savings in dollars for the owners. More important would be the energy no longer expended for chemical fertilizer, especially nitrogen production. Production, packaging transport, distribution and application of 1 lb. of nitrogen fertilizer requires 2 lb. of fossil fuel, for 1 lb. of phosphorus .33 lb. of fuel is required, and 1 lb. of potassium takes .21 lb. of fuel. (195)

Effects of Local Production

Individual-Financial:

outside labor saved = see Section 10

≈10% less grocery trips (if 2/wk. of 10 mi. round trip, gas @ $1.30/gal.-not incl. 30¢ mi. on vehicle & time) = $10.40/yr.

some % of Societal Benefits = ++

Societal-Economic:

increased health of local rural economy from less outside expenditures for food fuel and fertilizer = ++

increased health of urban economy through less job competition as more labor is reabsorbed into rural areas= ++

decreased environmental degradation due to lower transportation requirements for food (1.5×10^{5} BTU/yr.) fuel and fertilizer = ++

Balance of Payments = ++

Security = ++

Jobs and Labor

Barry Commoner's 4th Law of Ecology (There is no such thing as a free lunch.) (45) applies strongly to the realm of labor in the food, fuel and fertilizer systems. "For one unit of our work, we have been able to obtain 50 units of work done for us by fossil fuels. We have been using approximately 10% of our work to obtain such energy, which means that fossil fuels have had the effect of temporarily increasing our total ability to do work by almost six times." (18) The environmental and social costs of this "free lunch" have begun to compel us to include these costs in our financial and economic accounting.

The value of human labor and society's respect for human skills and effort is relatively small when 'energy slaves' "can do our work at 2% of the costs" (18) Most humans, functioning at 2.5% energy efficiency, can sustain an output of 256 BTU/hr.(195) A gallon of gasoline produces the work equivalent of three 5 day, 8 hr./day weeks of human effort. (155) Farm labor, at $3./hr. for 500 BTU/hr. work cost $6000/10^{6}BTU compared to fossil fuel's cost of $15..

The release of millions of small farmers and farm laborers from the land is often cited as an indispensable condition, the sine qua non of progress. (150) Agribusiness keeps on claiming that "food is being produced in greater amounts than ever before, and with greater efficiency in terms of human labor. Moreover, persons released from the ranks of farm labor...are now increasing the national wealth by producing goods and services in other aspects of the economy. (61)

Since 1952 about three million farmers have been "released from the land"/gone out of business. (120) The average labor input per acre of corn fell by 60% from 1945-1970. (213) Between 1970 and 1980 the total hours of farm work declined by another 22%. (27) While this has made more workers available (at lower rates) to the nation's industrial centers, there are numerous social costs of this displacement which include increased wlfare payments, invidious costs of urban over-crowding, (127) and deterioration of rural economies and quality of life. "Release from the land" is impossible as our lives depend on these ecosystems, but it is the basic cause of alienation from and ignorance of our biological life support systems.

In 1977, food and releted inductries accounted for 25% of the U.S. GNP and employed about 20% of the work force. (214) Farm production employs 4.5% of the work force, production of farm supplies employs 5%, and food processing and distribution 10%. (150) While the U.S. food system has reduced on-farm labor, it has provided much employment that did not exist 20, 30 or 40 years ago so that the idea of a reduction in food system labor input may actually be a myth. (195)

In regard to jobs and energy, centralized fossil fuel and nuclear productions supply systems, like the centralized agricultural production system, provide much less opportunity for employment then decentralized systems. Studies have shown that investments in solar power development (by its nature decentralized) provides $2\frac{1}{2}$ to 4 times more employment than nuclear fission. (83) (See also Table opposite page 7-3)

Many farmers today must have outside work to earn the money to pay for farm inputs. In most analyses, while the on-farm labor required for various self-supporting activities is charged to those activities, the savings in necessary off-farm labor done to earn the money to pay for the activities of others is not given credit. Self-sustaining activities can be done at one's own pace, while off-farm money-making activities are generally under the control of others. Being one's own boss is of considerable value, and outside work requires travel time and vehicle upkeep, so in this account, on-farm labor is figured to cost $3./hr. while off-farm labor made unnecessary by having and operating the system is valued at $5./hr.

In economics, productivity is usually defined as production output per labor input. (45) In the bioeconomics of renewable resources, productivity must be concerned with efficient day-to-day and year-to-year utilization of solar energy and maintenance of and improvement of the soil. The numerous possible symbiotic arrangements of the biotechnological systems discussed in this paper allow the operator to take increasing advantage of the natural energy flows and nutrient cycles of the biosphere.

Effects of System on Jobs and Labor

Individual-Financial:

system operation labor @ 50hr./weeks-	8.6 wk./yr.
outside labor saved @ $5/hr. & 50hr./wk.	
excluding CO_2 value-	10.8 wk./yr.
including CO_2 value-	16.8 wk./yr.
some % of Societal Benefits-	++

Societal-Economic:

Increase in rural employment opportunities:
a) construction provided over 2300 hr. of labor
b) potential operation of greenhouse could provide full employment and remuneration for at least one person

Rural economy stimulated by multiplier effect of purchase of local materials and income to local construction labor

Less overcrowding of urban centers as more rural jobs are available which would result ina more evenly distributed burden on the environment.

Security

In both local and national contexts, dependence on distant sources for daily food and energy requirements presents a handle for coercion. The more self-sufficient in food and energy needs a farm, rural community or nation is, the less it will be plagued by the vagaries of commerce and international affairs. I would suggest that a nation cannot approach self-sufficiency as a whole without each small part of that nation utilizing its own site-specific potential.

Agriculture is certainly our most basic industry. Gas shortages cause a few fights-food shortages tend to cause riots. The U.S. (and much of the world) agricultural community has become almost totally dependent on distant and uncontrolled energy sources. The possibilities suggested in Section 10 offer that community its most accessible avenues to independence. (Again note Shaffer et. al.'s investigation of digester/generator/alcohol integration) showing electrical production for 8% of U.S. homes, displacement of 65 mil. barrels of oil/year by alcohol ($2.275 billion) and displacement of 29 mil. barrels of oil/year by effluent nutrients (1.015 billion). (184)

Centralized energy production facilities make attractive targets since their disabling would wreak havoc with large populations. These large facilities are not conducive to security. The situation would be far different if every farm was at least self-sufficient if not a producer of both food and energy.

Effects of System on Security

Individual-Financial:

increased self-sufficiency & independence of outside food and energy sources- ++
(true value determined upon failure of outside supply)

some % of social benefits- ++

Societal-Economic:

increased renewable self-sufficiency as a nation

decreased pressure on the environment as less waste is forced upon it and less fossil fuel is forced out of it

increased independence of crop production system

increased security of dispersed energy production and supply system

Section 14-1

Financial Analyses

A financial analysis is done with a view toward monetary costs and benefits by the individual carrying out the discussion. Social costs and other 'externalities' are often briefly considered at thend of these analyses, if indeed, they are mentioned at all. This methodology is not appropriate to the development of an ecologically sustainable society based on renewable resources. (See Section 7)

The analysis here has been done with the normally narrow view of financial effects. Included are system design expenses, construction materials and labor costs, operating labor and maintenance costs, and the obvious benefits of biogas, greenhouse food, pond feed and crop fertilizer. Not included are:

a) the numerous symbiotically-generated benefits discussed in Section 10:

b) the decreased necessity for outside labor via operation of the system which can easily be more than twice the operating labor;

c) national, state and local energy and pollution control tax credits;

d) the micro-environmental benefits to the owner's farm;

e) the percentage of larger societal effects.

An inflation rate of 5% has been used in these analyses. This is certainly an absolute minimum as energy prices are predicted to rise 2-4 times that rate and they will pull up the price of everything in the economy. How much will depend on the level of self-sufficiency which is attained by the general populaton. Some of the calculations have been done based on a 50 year lifetime. This is certainly not unreasonable considering the materials used in construction.

The near 10 year pay-back period was also calculated with the insular perspective of dollars in and dollars out. The multitude of additional considerations surrounding this system would result in a fraction of that period.

System Values

Costs item	Total	Digester	Gasline	Greenhouse	Pond	System
Design Engineering	$4,700.—	$3,000.—		$1,500.—	$200.—	
Labor @ $3/hr.	11,655.—	5,970.—	$560.—	3,650.—	1,475.—	
Materials	12,909.—	8,007.—	986.—	3,212.—	638.—	
Excavation	3,765.—					$2,765.—
Monitoring Equip.	333.—	313.—		20.—		
Misc. Tools	1,115.—					1,115.—
Totals	$30,988.—	$11,290.—	$1,546.—	$8,352.—	$2,313.—	$3,880.—
minus labor	19,333.—	11,320.—	986.—	4,732.—	838.—	

Related Costs

	Total	Digester	Gasline	Greenhouse	Pond	System
labor/yr.	$875.—	$210.—		$548.—	$117.—	
Maintenance/yr.	25.—					$25.—
Total add. cost	$900.—	$210.—				

Benefits/yr.

	Total	Digester	Gasline	Greenhouse	Pond	System
Gas 150,000 ft^3 CH_4	$675.—	$675.—				
Food	1672.—			$1,672.—		
Feed	40.—				40.—	
Fertilizer	105.—	105.—				
Total Benefits/yr.	$2492.—	$780.—		$1,672.—	$40.—	

Cost Analysis

1a-1) Costs over 15 year period

US Benefits – Computed yearly

$$\frac{\text{Total System Cost}}{15\ \text{yr}} + \text{Additional yearly costs} = \text{cost/yr.}$$

(Totals including labor cost)

$$\frac{\$30,988.–}{15\ \text{yr}} + \$900.– = \$2,066.– + \$900.– = \$2,966.–$$

cost/yr. = \$2,966.–

Benefits yr. = \$2492.–

Benefit/cost ratio = 84%

[meaning – will recover 84% of yearly cost/yr for 15 yrs.]

(Totals excluding labor costs)

$$\frac{\$19,333.–}{15\ \text{yr}} + \$25.– = \$1,289.– + \$25.– = \$1,314$$

Benefit/cost ratio = 190%

[will recover 190% of yearly cost/yr. for 15 yrs]

1a-2) Costs over 50 yr. period

US Benefits computed yearly

$$\frac{\text{Total System cost}}{50\ \text{yr.}} + \text{Additional yearly costs} = \text{cost/yr.}$$

(including labor)

$$\text{cost/yr} = \frac{\$30,988.–}{50\ \text{yr}} + \$900.– = \$620.– + \$900.– = \$1,520.–$$

Benefit cost ratio = 164%

(excluding labor)

$$\text{cost/yr.} = \frac{\$19,333.–}{50\ \text{yr}} + \$25.– = \$387.– + \$25.– = \$412.–$$

Benefit/cost ratio = 605%

Cost Analysis
Taxes

2) Assuming family of four – with labor costs, without energy and pollution credit

yr. 1

Taxable income	$5,000.–	$10,000.–	$15,000.–	$20,000.–	$30,000.–
Tax (1981)	–0–	373.–	1,231.–	2,243.–	4,899.–
Depreciation Acres 15 yr.	1,549.–	1,549.–	1,549.–	1,549.–	1,549.–
Adjusted Gross Income	3,451.–	8,451.–	13,451.–	18,451.–	28,451.–
Tax (1981)	–0–	149.–	955.–	1,920.–	4,414.–
Investment Credit	–0–	149.–	955.–	1,920.–	3,099.–
Carry over or back (x)	3099.–	2,950.–	2,144.–	1,179.–	–0–
Tax after credit	–0–	–0–	–0–	–0–	1,315.–
Savings					
on self-employment tax @ 9.3%	144.–	144.–	144.–	144.–	144.–
on income tax	–0–	373.–	1,231.–	2243.–	3,584.–
Total saved yr. 1	144.–	517.–	1,375.–	2,387.–	3,728.–

(x) can carry back 3 years and forward 15 years

yr. 2

Tax (1981 tables)	–0–	373.–	1,231.–	2,243.–	4,899.–
Depreciation	1,549.–	1,549.–	1,549.–	1,549.–	1,549.–
AGI	3,451.–	8,451.–	13,451.–	18,451.–	28,451.–
Tax	–0–	149.–	955.–	1,920.–	4,414.–
Inv. credit	–0–	149.–	955.–	1,179.–	–0–
Carry over	3099.–	2,801.–	1,189.–	–0–	–0–
Tax after credit	–0–	–0–	–0–	741.–	4,414.–
Savings					
on SE tax @ 9.3%	144.–	144.–	144.–	144.–	144.–
On Inc. tax	–0–	373.–	1231.–	1,502.–	485.–

Cost Analysis

1b) Assuming 5% inflation in Benefits and yearly labor cost per year

	yr 1	yr 5	yr 15	yr 50
Benefits	$ 2,492.–	$ 3,029.–	$ 4,934.–	$ 27,216.–
(including labor cost)	1,520.–	1,715.–	2,195.–	6,020.–
Benefit/cost ratio (z)	164%	177%	225%	452%
(excluding labor) - cost	412.–	418.–	431.–	537.–
Benefit/cost ratio (y)	605%	725%	1145%	5068%

(z) 164% = $\frac{\$2,492.–}{\$1,520.–}$ (per 1a-2) (ratio = $\frac{\text{Benefit in yr.}}{\text{Cost over 50 yr.}}$)

(y) 605% = $\frac{\$2,492.–}{\$412.–}$ (per 1a-2) (ratio = $\frac{\text{Benefit in yr.}}{\text{Cost over 50 yr.}}$)

1c) Assuming borrowed $20,000.– for 15 yr. at simple interest of 10% and 5% inflation per yr.

	yr 1	yr 5	yr 15	yr 50
Benefits	$ 2,492.–	$ 3,029.–	$ 4,934.–	$ 27,216.–
Cost with labor	$ 4,453.–	$ 4,648.–	$ 5,128.–	$ 5,620.–
Cost w/o labor	3,358.–	3,364.–	3,377.–	150.–
Benefit/cost ratio (with labor)	56%	65%	96%	484%
Benefit/cost ratio (w/o labor)	74%	81%	146%	18,149%

Cost Analysis
Pay Back

3) Assuming Family of Four - $20,000.- Income level - labor costs included 5% inflation and money borrowed at 10%

	1st yr.	2nd yr.	5th yr.	10th yr.	15th yr.	50th yr.
Benefits	$2,492.—	$5,109.—	$13,769.—	$31,341.—	$53,770.—	$521,388.—
Tax savings	2,387.—	4,033.—	5,434.—	7,769.—	10,104.—	10,104.—
Total Benefits	$4,879.—	9,142.—	19,203.—	39,110.—	63,874.—	531,492.—
Cost	31,888.—	32,870.—	35,683.—	40,438.—	45,163.—	86,488.—
Benefits/cost ratio	15%	28%	54%	97%	142%	660%

Pay Back After 10 Years

TABLE 20 Energy Consumption Within the U.S. Food System (100)

Sector	%of U.S. total energy use	% of U.S. food system
on-farm direct energy	1.0	6
input due to chemicals and transportation	1.9	12
food processing	4.8	30
distribution systems	1.8	10
commercial food services	2.8	17
home food preparation	4.3	26

Section 15-1

Net Energy Analysis

A net energy analysis compares the energy inputs required by some thing or action to its energy output. It is the recent energy crisis which stimulated such investigations so that quantitative information for them is still quite limited.

These analyses are also extremely complex and entire theses can focus on very small items. For instance the inputs for chemical nitrogen fertilizer would begin with the fossil fuel and human energy required for production, packaging, marketing, transportation, distribution, storage and application of the fertilizer itself. To this must be added the fossil fuel and human energy that went into the facilities and vehicles for production, packaging, etc.. To this again must be added the energy that went into getting the energy that was so used. In addition there is the energy required for correcting the environmental damage done by all of that energy use as well as the erosion and water pollution caused by the fertilizer's use. The energy output of chemical nitrogen fertilizer would be the percentage of food energy value in the crop produced minus the inputs that must be attributed to solar radiation, other fertilizers and the soil itself. In this instance, the work has not been done but would likely result in a very large negative number.

The digester/greenhouse/pond system considered here has many such aspects so that a complete analysis has not been possible. Available figures have been used where possible but for most aspects it has only been possible to mention many of the potential effects. Most of these effects were mentioned throughout Sections 10-15 so that only a brief review will be included here.

The U.S. food system (including animal feed and fertilizer) has lost contact with the basic biological processes that support the system. Huge fossil fuel (and nuclear power subsidies are currently able to mask this loss of contact but the cost has been a near total dependence on these fuels. Nearly every small step within the food system requires a larger amount of energy than the nutritional energy in the food. The digester/greenhouse/pond system would help significantly in limiting many of those energy expenditures.

Table 20 shows current energy use in the farm system. A system like Draco II the indirect inputs would be significantly decreased. (Hauling and spreading 10 tons of manure/acre takes about 11 gal. of gasoline by production of chemical fertilizer (at 112lb. N, 31 lb. P, and 60 lb. K/acre) requires about 39 gal. of gasoline and spreading takes one gallon. (137) Food processing would still take a large amount of energy, but many of the nutrient removal and replacement steps would be avoided along with much of the excessive energy expensive packaging. Energy consumption for distribution/transportation would be reduced to a minimum.

A complete analysis of these system related benefits would have to include the energy saved, the energy needed to produce and distribute the energy saved and the avoided energy cost of environmental repair from less energy production and consumption (as well as the energy to produce and distribute the energy for environmental repair).

Each of the components in this system increased the opportunity for solar energy utilization-the digester releases photosynthetically fixed sunlight; the greenhouse utilizes sunlight for photosynthesis and heat; and the pond utilizes sunlight for photosynthesis only. (An alcohol still would also make available photosynthetically fixed energy.) The symbiotic arrangement of these components allows them to support each other so that much less energy and labor are required than if each were separate.

TABLE 21

Energy Inputs for System Construction

Input	# and units	BTU input x 10^6	Ref.
Man Hours	2331 hr.	1.15	(12)
Heavy Equipment Operation	80 hr.	?	-
Materials-			
plaster	800 lb.	2.87	(15)
cement & mortar	3600 lb.	15.6	(15)
sand & gravel	60 ton	6.0	(71)
concrete	35 yd.	90.8	(85)
block	3520-8"	112.	(85)
fabricated steel	348 lb.	7.90	(85)
concrete mesh	300 lb.	7.26	(85)
rebar	2860 lb.	44.8	(85)
steel plate	360 lb.	9.49	(71)
galv. steel pipe	400 lb.	11.0	(71)
steel pipe	2854.1 lb.	64.8	(85)
flashing	40 lb.	3.84	(85)
stainless steel bolts	30 lb.	1.53	(71)
nails	58 lb.	1.97	(85)
bolts and screws	152 lb.	4.05	(85)
plywood	1216 sq. ft.	7.03	(12)
soft planed lumber	250 bd. ft.	1.96	(12)
hard rough lumber	1200 bd. ft.	11.8	(85)
plastic products	358 lb.	1.43	(15)
polystyrene	350 lb.	3960.	(71)
glass	595 sq. ft.	27.8	(134)
roof paint & cement	250 lb.	1.73	(85)
roll roofing	270 sq. ft.	2.97	(85)
felt paper	50 lb.	.682	(85)
paint & oil	18 gal.	8.79	(85)
		4413.	
		(453. excluding insulation)	

For proper decisions regarding building materials "a detailed framework of all the energy uses in materials, products, and complete assemblies is required. Considering the importance of these decisions from a material point of view, it is astonishing that such basic data are unavailable." (194) There has however been some preliminary work done and the great variety of products that went into Draco II have been squeezed into the classifications seen above. The expanded polystyrene insulation board accounts for over 89% of the energy required for construction of the system. (Had I known this at the time, alternatives would have been further investigated.) Consider ing only biogas production of 150,000 ft^3/year @ $4.50/MCF the energy payback period would be 29.42 years. (Not including insulation payback would be 3.02 years.) This would be much shorter (perhaps by $\frac{1}{2}$ or more) if all the energy aspects of the system were included.

Section 16-1

Department of Energy Project Conclusions and Future Efforts

Although this digester/greenhouse/pond system requires a substantial investment of funds and energy, it pays back both invested capital and invested energy within a very reasonable period of time. The system's durability will allow it to continue giving service with low up-keep requirements for many decades after recovery of the original investment. The percent of potential production attained depends largely on the labor invested in it but this labor brings returns which justify every effort invested.

Just as with other livestock, efficient operation of the system at anywhere near its potential will require several years experience. Monitoring will continue without Department of Energy support throughout this period.

Future efforts at developing the potential of this system will include experimentation with Spirulina growth in September, 1982, construction of a fish pond within two years, and introduction of a fuel alcohol still into th greenhouse within five years. By this time more reliable data should be available on the various aspects of the system including actual biogas and greenhouse production, the pond production of livestock feed, the energy value of digester/greenhouse integration, and the value of digester effluent as fertilizer.

Integrated renewable energy systems, such as that described here, hold great potential for relieving agriculture's dependence on environmentally destructive fossil fuels. This offers greater individual security for farmers and will lead to much greater security for the nation as a whole.

REFERENCES

1) Abeles, Tom P.; David Ellsworth. "Capturing the Sun Through Bioconversion-An Overview of Biomass Research and Activities". Alternative Sources of Energy. May-June 1979

2) Abeles, Tom P.; David Freedman, David Ellsworth, Luc DeBaere, Bibliography of Anaerobic Digestion-Energy and Economic Assesment of Anaerobic Digesters and Biofuels for Rural Waste Management. The Environmental Protection Agency. June 1978

3) Abeles, Tom; David Freedman, David Ellsworth, Luc DeBaere. Energy and Economic Assesment of Anaerobic Digesters for Rural Waste Management. The Environmental Protection Agency. June 1978

4) Abeles, Tom P.; E.M. Dale. Safety and Design Considerations for Farm Digesters. Environmental Protection Agency. (R 8044570-01)

5) Achorn, Frank P.. "Chemical Fertilizers". Proceedings Bioenergy. 1980

6) -----, "The Adaptable Fuel". Biotimes. The International Biomass Institute. July-August 1979

7) -----, "An Algal Regenerative System for Single Family Farms and Villages" IRCWD News. WHO International Reference Center for Wastes Disposal. 1976

8) Anderson, Larry L.. Energy Potential From Organic Wastes: A Review of the Quantities and Sources. U.S. Dept. of the Interior. 1973

9) -----, The Animal-Methane-Chlorella Cycle. Chinese-American Joint Commission on Rural Reconstruction. August 1965

10) -----, Aquaculture Development in China. Aquaculture Development and Coordination Programme. U.N. Development Programme-Food and Agriculture Organization of the U.N. 1979

11) Augenstein, Don. Technical Principles of Anaerobic Digestion. Biotechnology for Utilization of Organic Wastes, Universidad Autonoma Metropolitana Iztapalapa, Mexico January 1976

12) Bainbridge, David A.. The Second Passive Solar Catalog. Passive Solar Institute

13) Barnett, Andrew; Leo Pyle, S.K. Subramanian. Biogas Technology in the Third World-A Multidisciplinary Review. The International Development Research Center, Canada. 1978

14) Barth, C.C.; D.T. Hill. Energy and Nutrient Conservation in Swine Waste Management. American Society of Agricultural Engineers. June 1975

15) Bendavid-Val, Arram. "Jobs, How Many, What Kind, for Whom?". Rain Magazine

16) Bender, Tom. Emerging Energy Policy Principles . Office of Energy Research and Planning, Office of the Governor, State of Oregon. 1974

17) Bender, Tom. "Energy Conservation in Housing". Rain. 1973

18) Bender, Tom. "Shring Smaller Pies" Rain. Feb. 1975

19) Beneman, John R.. Energy From Wastewater Aquaculture Systems. Ecoenergetics Inc.

20) Beneman, John R. Phd.; Ben L. Koopman, Daniel C. Baker, Joseph C. Weissman, William J. Oswald Phd.. A Systems Analysis of Bioconversion with Microalgae. Sanitary Engineering Research Lab, U. of C. Berkely

21)Beneman, John R.; Joseph C. Weissman, Ben G. Koopman, William J. Oswald. "Energy Production by Microbial Photosynthesis". Nature. July 1977

22)Bezdicek, D.F., M.H. Ehlers, R.E. Hermanson, J.M. Sims, J. Conrath. Nutrient Budget in a Dairy Anaerobic Lagoon-Evaluation for Land Application. College of Agriculture Research Center, Washington State University. Oct. 1977

23)Bhatia, Ramesh. "Economic Appraisal of Biogas Units in India: Framework for Social Benefit Analysis". Economic and Political Weekly, Vol. XII: 33-34. Aug. 1977

24)Biers, Matt, Axell Elyse. "Organic Farms Find New Fans". Soft Energy Notes, Vol.6:3 Dec.-Jan. 1981

25)Boersma, L.; E.W.R. Barlow, J.R. Miner, H.K. Phinney, J.E. Oldfield."Protein Production Rates by Algae Using Swine Manure as a Substrate". Energy Agriculture and Waste Management. Agricultural Waste Management Conference, Cornell. Wm. J. Jewell, Ed. 1975

26)Boersma, L.; E.W.L. Barlow, J.R. Miner, H.K. Phinney, J.E. Oldfield. Protein Production Rates by Algae Using Swine Manure as a Substrate. Office of Water Resources Research and Technology U.S.D.I.

27)Booram, C.V. Jr.. Land Application of Swine Residue for Integrated Crop Production Iowa Agriculture and Home Economics Experiment Station. June 1977

28)Brown, Lester R.. Worldwatch Paper 20, The Global Economic Prospect: New Sources of Economic Stress. Worldwatch Institute. May 1978

29)Brown, Susan Jean; J. Clair Batty. Energy and Our Food System-A Microscale View. Dept. of Mechanical and Manufacturing Engineering Utah State University. 1977

30)Bryan, Edward H. Phd. The Potential Role of Aquaculture in Management of Wastewater. National Science Foundation. Sept. 1980

31)Buckingham, Jerry. "Alternative Sources of Energy". Biomass. Nov.-Dec. 1981.

32)Bullard, Clark III; Bruce Hannon, Robert Herendeen. Energy Flow Through The United States Economy. Center for Advanced Computation(Energy Research Group). 1975

33)Burford, John. Manure vs. Anaerobic Residue. Biogas of Colorado.

34)Burford, John L.Jr.; Fred T. Varani, Susan Schellenbach, Wayne Turnacliff, Shelley Don, Bill Pace. Energy Potential Through Bioconversion of Agricultural Wastes:Phase II. Biogas of Colorado Inc. Oct. 1977

35)Buttel,Frederick H.; William Lockeretz, Martin Strange, Elinor C. Terhune. Energy and Small Farms-A Review of Existing Literature and Suggestions Concerning Further Research National Rural Center Small Farms Project. 1980

36)Chen, Shepley S.C.. The CO2 Solar and Geothermal Energies-Microalgae-Fish System. International Symposium on Biogas, Microalgae and Livestock Wastes. Sept. 1980

37)Chen, T.H.; D.L. Day. Feedlot Biogas as Process Fuel for Farm Alcohol Plants. International Symposium on Biogas. 1980

38)-----, Cheyenne Community Solar Greenhouse Food and Nutrition Program. Community Action of Laramie County Inc. Community Services Administration.

39)Chien, Tse-Shu. Biogas-An Important Source for Rural Areas. Lab of Soil Microbiology Chekiang Ag. U. Hangchow, Chekiang. May 1981

40)-----, China, Azolla Propagation and Small Scale Biogas Technology. FAOIUNDP Study Tour Report. Food and Agriculture Organization of the U.N. 1978

41)-----,"Chinese and Indian Gas Plants: A Comparison". Biogas Newsletter, Nepal No.7 Winter 1979

42)Chiu, R.J.; H.I. Liu, C.C. Chen, M.J. Perng, P. Soong, Paul L.C. Hao. The Autotrophic Growth of Spirulina Platensis in Mass Culture. International Symposium on Biogas, Microalgae, and Livestock Waste. Sept. 1980

43)Chiu, R.J.; H.I. Liu, C.C. Chen, Y.C. Chi, H. Shao, P. Soong, Paul L.C. Hao. The Cultivation of Spirulina Plantensis with Fermented Swine Manure. International Symposium on Biogas, Microalgae and Livestock Waste. Sept 1980.

44)Clegg, Peter; Derry Watkins. The Complete Greenhouse Book-Building and Using Greenhouses from Cold Frames to Solar Structures. 1978

45)Commoner, Barry. The Closing Circle-Nature Man and Technology. Alfred A. Knopf. 1971

46)-----, Construction of 'Cross-Plots'. Environmental Action Reprint Service, The Joint Committee on Atomic Energy. 1973

47)Coppinger, Elizabeth; David Baylon, Ken Smith. Report on the Design and First Year Operation of a 50,000 Gallon Anaerobic Digester at the State Honor Farm, Monroe, Wash. Ecotope Group. July 1978

48)Crook, Michael (translator) Ariane van Buren (Ed.). A Chinese Biogas Manual Popularizing Technology in the Countryside. Office of the Leading Group for the Propagation of Marshgas, Sichuan Province, Peoples Republic of China. 1976

49)Culley, Dudley D.; Ernest A. Epps. "Use of Duckweed for Waste Treatment and Animal Feed". Journal Water Pollution Control Federation. Feb. 1973.

50)-----,Cutting Energy Costs, The 1980 Yearbook of Agriculture. U.S. Dept. of Agriculture

51)-----, Dairy Science Waste Utilization Research. Louisiana State University.

52)Da Silva, E.J.. Biogas Generation: Developments, Problems and Tasks-An Overview. in Conference on Bioconversion of Organic Residues for Rural Communities. The United Nations University. Nov. 1979.

53)Davis, Leslie; Dennis Kensil, Bill Lazar, Bill Yanda, Susan Yanda (The Solar Sustenance Team). Solar Greenhouse Training Project: Final Report. The Energy Extension Service State of New Mexico, Energy and Materials Dept. April 1979.

54)Day, D.L. Phd.. Processing Manure For Use as Food Ingredients.Paper for International Symposium on Biogas, Microalgae and Livestock Wastes. Sept. 1980

55)-----, "Dousing Sewage with Baking Soda". Business Week p. 90d. June 1976

56)Drucker, Charles. "Jobs and Energy on Long Island-Employment Potential of Energy Scenarios Compared". Soft Energy Notes. Feb. 1980.

57)-----, Process Feasability Study: The Anaerobic Digestion of Dairy Cow Manure at the State Reformatory Honor Farm, Monroe, Wash. Ecotope Group. State of Washington, Dept. of Ecology. January 1975.

58)Ellsworth, David; Tom Abeles. Methane Production for Your Farm.

59)-----, Energy for Rural Development-Renewable Resources and Alternative Technologies for Developing Countries. National Academey of Science Commission on International Relations. 1976.

60)-----, Energy For Rural Development Supplement. National Research Council. 1981

61)-----, Energy Use in Agriculture-Now and For The Future. Council For Agricultural Science and Technology. August 1977.

62)Eusebio, Jose A.; Beatriz I. Rabino. "Recycling System in Integrated Plant and Animal Farming". Research on Biogas in Developing Countries. March/April 1978.

63)Fairbank, W.C.. "Fuel From Livestock Wastes: An Economic Analysis" Agricultural Engineering. Sept. 1974.

64)Farlin, Stanley D.; Ferry Klopfenstein. "Utilization of Distiller's Grains for Beef Feeding". Earth Energy Vol. 1:8, May 1980.

65)Fischer, J.R.; D.M. Sievers, C.D. Fulhage. "Anaerobic Digestion in Swine Wastes" Energy Agriculture and Waste Management, Cornell Agricultural Waste Management Conference. Wm. J. Jewell Ed. 1975

66)Fischer, Anthony C.; Frederick M. Peterson. "The Environment in Economics-A Survey" Resources for the Future. March 1976.

67)-----, Food Fuel And Fertilizer From Organic Wastes. Ad Hoc Panel of the Advisory Committee on Technology Innovation Board on Science and Technology for International Development. 1981

68)Fowler, John M.. Alternative Energy Sources-Environmental Impacts. National Science Teachers Assoc.. 1977.

69)Fox, R.D.. Circular Letter No. 16. World Council of Churches-Program Unit on Justice and Service. 1975.

70)French, David. The Economics of Renewable Energy Systems in Developing Countries. al Dir Iyyah Institute U.S. Agency for International Development. Jan. 1979

71)Friend, Gil; David Morris. Kilowatt Counter. Institute For Local Self-Reliance. 1976.

72)Fry, John L.. Practical Building of Methane Power Plants For Rural Energy Independence. (Standard Printing) 1974.

73)-----, Fuel Alcohol on the Farm-A Primer on Production and Use. U.S. National Alcohol Fuels Commission. 1980.

74)-----, Fuel From Farms-A Guide to Small Scale Ethanol Production. Solar Energy Information Data Bank, Solar Energy Research Institute, U.S. Dept. of Energy. Feb. 1980

75)Geller, Howard. "The Economic Feasibility of Methane Generation on a Central Massachusetts Dairy Farm". Science Technology and Society Review. Sept. 1976.

76)Godbole, S.H. Dr.. "Use of Water Hyacinth as an Additive in Biogas Production". Biogas Newsletter. August 1980.

77)Golueke,C.G.; W.J.Oswald.. "An Algal Regenerative System for Single Family Farms and Villages" Compost Science. May/June 1973

78)Golueke, Clarence G.; William J. Oswald. "Power From Solar Energy-Via Algae Produced Methane". Solar Energy Vol. 7, No. 3, 1963.

79)Golueke, C.G.; W.J. Oswald, H.B. Gotaas. Anaerobic Digestion of Algae. Sept. 1956.

80)Gorenflo, Louise; Dennis Gregg, David Weaver. Farm and Rural Energy Planning Manual. Institute for Ecological Policies. 1981.

81)Gregerson, Hans M.; Arnoldo H. Contreras. Economic Analysis of Forestry Projects. Food and Agriculture Organization of the U.N. 1979.

82)Gregg, Dennis."Personal Communication". Alternative Energy Farm Project. 1982.

83)Grossman, Richard; Gail Daneker. Energy, Jobs and the Economy. Alyson Publications Inc. 1979.

84)Haliburton, J.D.; H.M. Lapp, M.A. Stevens. The Energy Balances in a Pilot-Scale Anaerobic Digester. Canadian Society of Agricultural Engineering. Aug. 1977.

85)Hannon, Bruce; Richard G. Stein, B.Z. Segal, Diane Serber. "Energy and Labor in the Construction Sector". Science Vol. 202. Nov. 1978.

86)Hansen, R.W.; J.M. Harper, M.L. Stone, G.M. Ward, R.A. Kidd. Manure Harvesting Practices: Effects of Waste Characteristics and Run-Off. Environmental Research Lab. Office of Research and Development, U.S. Environmental Protection Agency. Dec. 1976.

87)Hashimoto, A.G.; R.L. Prior, Y.R. Chen. Methane and Biogas Production Systems for Beef Cattle Manure. Great Plain Extension Seminar on Methane Production From Livestock Manure, Liberal, Kansas. Feb. 1978.

88)Hassan, A.E.; H.M. Hassan, R.N. Smith. "Energy Recovery and Feed Production From Poultry Wastes". Energy, Agriculture and Waste Management. Cornell Agricultural Waste Management Conference. Wm. J. Jewell Ed. 1975.

89)Hayes, John; Drew Gillett, Eds.. Proceedings of the Conference on Energy-Conserving, Solar-Heated Greenhouses. Marlboro College. Nov. 1977.

90)Hayes, T.D.; W.J. Jewell, J.A. Chandler, S. Del'Orto, K.J. Fanfoni, A.P. Leuschner, D.F. Sherman.. Methane Generation From Small Scale Dairy Farms. Biogas Alcohol Seminar (Cornell U.) Oct. 1979.

91)Heisler, Michael. Biogas Filtration and Storage. Cornell Conference on Farm Methane Production. March 1981.

92)Henderson, Hazel. The Politics of the Solar Age: Alternatives to Economics. Anchor Books. 1981.

93)Henderson, Upton B.; Frank S. Wert. Economic Assessment of Waste Water Aquaculture Treatment Systems. USEPA Environmental Research Lab. Ada, Okla. Dec. 1976.

94)Hill, L.D; S. Erickson. "Economic Restraints on the Reallocation of Energy for Agriculture". Energy, Agriculture and Waste Management. Cornell Agricultural Waste Management Conference. Wm. J. Jewell Ed. 1975.

95)Hillman, William S.; Dudley D. Culley Jr.. "The Uses of Duckweed". American Scientist Vol. 66. July- ugust 1978.

96)House, D..The Compleat Biogas Handbook. At Home Everywhere. March 1978.

97)Hunt, Fern E.. "How to Save Energy Preparing Foods". Cutting Energy Costs. USDA Yearbook of Agriculture. 1980.

98)Ifeadi, C.N.; J.B. Brown Jr.. "Technologies Suitable for Recovery of Energy From Livestock Manure". Energy, Agriculture and Waste Management. Cornell Agricultural Waste Management Conference. Wm. J. Jewell Ed. 1975.

99)Jackson, H.A.; P. Van Die. Energy Technology for Primary Agricultural Production Greenhouses and Waste Heat. Proceedings of the Work Planning Meeting on Energy in the Food System. Agriculture Canada. 1979.

100)Jackson, Wes; Marty Bender. "American Food: S/oil and Water". Soft Energy Notes. Dec.-Jan. 1981.

101)Jeschke, John 1.; Donald L. Day, Walter Lemke. Erodability Factor of Beef Cattle Manure. American Society of Agricultural Engineers. June 1974.

102)Jewell, William J..Agricultural Waste Management-Energy From Agricultural Waste Methane Generation. Dept. of Agricultural Engineering, N.Y. State College of Ag. and Life Sciences. No. 397.

103)Jewell, W.J.; H.R. Capener, S. Dell;Orto, K.J. Fanfoni, T.D. Hayes, A.P. Leuschner, T.L. Miller, D.F. Sherman, P.J. Van Soest, M.J. Wolin, W.J. Wujik. Anaerobic Fermentation of Agricultural Residue: Potential For Improvement and Implementation. U.S. Dept. of Energy. Feb. 1978.

104)Jewell, W.J.; H.R. Davis, W.W. Gunkel, D.J. Lathwell, J.H. Martin Jr., T.R. McCarty, G.R. Morris, D.R. Price, D.W. Williams. Bioconversion of Agricultural Wastes For Pollution Control and Energy Conservation. Energy Research and Development Administration, Division of Solar Energy. Sept, 1976.

105)Jewell, W.J.; S. Dell'Orto, K.J. Fanfoni, T.D. Hayes, A.P. Leuschner, D.F. Sherman. Anaerobic Fermentation of Agricultural Residue: Potential For Improvement and Implementation. U.S. Dept. of Energy. April 1980.

106)Jewell, W.J.; S. Dell'Orto, K.J. Fanfoni, R.M. Kabrick. "Economics of Plug Flow Methane Reactors". Cornell University Conference, Methane Tech For Agriculture. March 1981.

107)Jewell, W.J.; J.B. Petersen, E.G. Shrinath, W.T. Tseng, E.J. Kroeker, E.C. McGriff Jr. "Agricultural Wastes". Journal WPCF. June 1975.

108)-----, The Journal of the New Alchemists. The New Alchemy Institute. 1980.

109)Kapp, K.W.. The Social Costs of Business Enterprise. Spokesman University Paperback. 1950.

110)Keely, B.J.; J.W. Griffith. Life Cycle Cost Benefit Analysis, A Basic Course in Economic Decision Making.Dept.of Health Ed. and Welfare. August 1977

111)Klausner, S.D.. Manure Handling and Application Considerations Following Anaerobic Digestion. Agronomy Dept. Cornell U..

112)Klock, Glen O.. Estimating Two Indirect Logging Costs Caused by Accelerated Erosion. U.S.D.A. Forest Service. 1976.

113)Kollman, Victor H.;Darryl J. Kollman. Feasibility for Algae Production Phase II. The Four Corners Regional Commission.

114)Kolstad,Charles; Derrick Grimmer. "Heat Calculations for Greenhouses". Alternative Sources of Energy. Feb.-March 1979.

115)Kraft, Darrell R.. "Cost Effectiveness Considerations-Biogas From Farm Digesters", Proceedings-REACT. Biomass Energy Institute. 1978.

116)Kroeker, E.J.; H.M.Lapp, D.D. Schulte, J.D. Haliburton, A.B. Sparling. Methane Production from Animal Wastes II: Process Stability. Canadian Society of Agricultural Engineering. July 1976.

117)-----, The Land Report. The Land Institute. Winter 1981.

118)Lapp, H.M.. Methane Utilization-What Can You Do With Methane if You Have It? . Dept. of Animal Science-U. of Manitoba. 1975.

119)Lauer, D.A.. "Limitations of Animal Waste Replacement For Inorganic Fertilizers". Energy Agriculture and Waste Management. Cornell Agricultural Waste Management Conference. Wm. J. Jewell Ed. 1975.

120)Lerza, Catherine. Agriculture Fact Sheet. National Family Farm Education Project and Earthwork Center For Rural Studies.

121)----, "Livestock Waste Management With Pollution Control". North Central Regional Research Publication. June 1975.

122)Locher, Valerie A.. "The Solar Greenhouse, Heat From It or Eat From It". Inner Spaces. Oct. 1980.

123)Lockeretz, William; Robert Klepper, Barry Commoner, Michael Gertler,Sarah Fast, Daniel O'Leary, Roger Blobaum. A Comparison of the Production, Economic Returns and Energy Intensiveness od Corn Belt Farms That Do and Do Not Use Inorganic Fertilizers and Pesticides. National Science Foundation Program of Research Applied to National Needs. July 1975.

124)Loehr, Raymond C.. "Anaerobic Lagoons, Consideration in Design and Application" Transactions of the ASAE. 1968.

125)Loehr, Raymond C.. Animal Wastes-A National Problem. The American Socirty of Civil Engineers-Sanitary Engineering Division. April 1969.

126)Lucas, R.E.; M.L. Vitosh. Soil Organic Matter Dynamics. Michigan State U. Dept. of Crop and Soil Sciences. Nov. 1978.

127)Madden, J. Patrick; Delworth B. Gardner, Diana S. Branch, David Holland, Howard A. Osborn.. Production Efficiency and Technology for Small Farms. National Rural Center Small Farms Project. 1980.

128) Hadewell, Carl E.; John B. Martin, Billy G. Isom.. Environmental and Economic Aspects of Recycling Livestock Wastes-Algae Production Using Waste Products. Agricultural Economics Section Assoc. of Southern Agricultural Workers. March 1973.

129) Mahloch, J.L.; E.C. McGriff Jr.. "Agricultural Wastes" Journal WPCF. June 1974.

130) Marier, Don. "The Habitat Center". Alternative Sources of Energy. Feb.-March 1979.

131) Martin, J.H. Jr.; R.C. Loehr. Economic Analysis of Biogas Production And Utilization. 4th International Symposium on Livestock Wastes. April 1980.

132) Martin, John H. Jr.; Thomas E. Pilbeam, Raymond C. Loehr.. Nutritive Value of Anaerobically Digested Beef Cattle Manure as a Feed-Stuff. American Society of Agricultural Engineers. Dec. 1980.

133) Mathewson, Stephen W.. "Power Alcohol-An Overview". Alternative Sources of Energy. March-April 1980.

134) McCullagh, James C. Ed.. The Solar Greenhouse Book. Rodale Press. 1978.

135) McGarry, Michael G.; Jill Stainforth, Eds. Lee Thin, translator. Compost, Fertilizer and Biogas Production From Human Farm Wastes in the People's Republic of China. The International Development Research Center-Canada. 1979.

136) Merrill, Richard. "Ecosystem Farming" Political Ecology. Alexander Cockburn, James Ridgeway, Eds. 1979.

137) Merrill, Richard. "Toward a Self-Sustaining Agriculture" Radical Agriculture. Richard Merrill, Ed.. 1976.

138) Merrill, Richard; J.R. Fry. "Methane Digesters For Fuel Gas and Fetilizer". New Alchemy Institute, Newsletter No. 3. 1973.

139) -----, Methane Generation From Human Animal and Agricultural Wastes. National Academy of Sciences. 1977.

140) Mills, P.J.. A Comparison of an Anaerobic Digester and an Aeration System Treating Piggery Waste From the Same Source. The North of Scotland College of Agriculture. Waste Management Conference. April 1977.

141) Miner, Ronald J. Ed.. Farm Animal Waste Management. Agriculture and Home Economics Experiment Station, Iowa State U. of Science and Technology. May 1971.

142) Miner, J.R.; L. Boersma, J.E. Oldfield, H.K. Phinney. "Swine Waste Nutrient Recovery System Based on the Use of Thermal Discharges". Managing Livestock Wastes.

143) -----, Factors Involved in Land Application of Agricultural and Municipal Wastes. National Program Staff, Soil Water and Air Sciences, Agricultural Research Service U.S. Dept. of Agriculture. Oct. 1975.

144) -----, National Workshop on Algal Systems Proceedings. Indian Society of Biotechnology, Shri A.M.M Muragappa Chettiar Research Center-Photosynthesis and Energy Division. October 1980.

145) Okagaki, Alan; Jim Benson. County Energy Plan Guidebook-Creating A Renewable Energy Future. Institute for Ecological Policies. 1979.

146) Oswald, Willian. "Solar Energy Fixation With Algal-Bacterial Systems". Compost

Bottom of page cut off.

147)Oswald, William J.; Don M. Eisenberg. "Biomass Generation Systems as Energy Resources" Proceedings Bioenergy. 1980.

148)Oswald, William J.; Clarence G. Golueke. Large Scale Production of Algae. International Conference on Single-Cell Protein at Mass. Institute of Tech. Oct. 1967.

149)Pathak, Dr. B.S.; Er. A.P, Bhatnagar, Dr. Daljit Singh, Dr. K.S. Salariya, Dr. S.L. Jindal, Er. M.L. Gupta, Er. Sarangit Singh. Energy Balance and Utilization of Agricultural Waste on a Farm. Tata Energy Research Institute. 1980.

150)Peralman, Michael. "Efficiency in Agriculture; The Economics of Energy" Radical Agriculture. Richard Marrill, Ed. 1976.

151)Perelman, M.. "The Real and Fictitious Economics of Agriculture and Energy" Energy Agriculture and Waste Managrment. Cornall Agriculture and Waste Management Conference. Wm. J. Jewell Ed. 1975.

152)Pierotti, Anne R.S.M.; Albert J. Fritsch S.J.. Lifestyle Index-A Guide to Individual Energy Use. Citizen's Energy Project. 1977.

153)Pierotti, Anne R.S.M.; Andrew G. Keeler, Albert Fritsch S.J.. Energy and Food-Energy Used in Production, Processing Delivery nad Marketing of Selected Food Items. Center for Science in the Public Interest. 1977.

154)Pimentel, David. "Biomass Energy, Bonanza or Boondoggle" Soft Energy Notes. Dec.-Jan. 1981.

155)Pimentel, David. "Energy and Food" Political Ecology. Alexander Cockburn, James Ridgeway. 1979.

156)Pimentel, D.. "World Food, Energy, Man and Environment" Energy, Agriculture and Waste Management Cornell Agricultural Waste Management Conference. William J. Jewell Ed.. 1975.

157)Pimentel, David; Donald Nafus, Walter Vergara, Dan Papaj, Linda Jaconetta, Marty Wulfe Linda Olsvig, Kerry Frech, Mark Loye, Ellen Mendoza. Biological Solar Energy Conversio and U.S. Energy Policy. Cornell University Agricultural Experiment Station, N.Y. State College of Agriculture and Life Sciences, American Institute of Biological Sciences. 1978.

158)Pimentel, David; Donald Nafus, Walter Vergara, Dan Papaj, Linda Jaconetta, Marty Wulfe Linda Olsvig, Kerry Frech, Mark Loye, Ellen Mendoza. Biomass Energy Conversion. Dept. of Entomology and Section of Ecology and Systematics. 1978.

159)Pimentel, David; Elinor Cruze Terhune. "Energy and Food". Annual Review of Energy 2:171-195 1977.

160)Pimentel, David; Elinor C.Terhune, Rada Dyson-Hudson, Stephen Rochereau, Robert Samis, Eric A. Smith, Daniel Denman, David Reifschneider, Michael Sheperd. "Land Degradation: Effects on Food and Energy Resources". Science Vol. 194. Oct. 1976.

161)Poincelot, Raymond P.. A Scientific Examination of the Principles and Practice of Composting . Dept. of Biochemistry, The Conn. Ag. Experiment Station. Summer 1974.

162)Price, Donald R.. "Where Farm Energy Goes, Part One of Overview". Cutting Energy Costs-The 1980 Yearbook of Agriculture. Jack Hayes Ed. 1980.

163)Price D.R.; W.H. Cunkel, C.I. Casler. "Accounting of Energy Inputs For Agricultural

164)-----, Program Announcement and Grant Application Region III. U.S. Dept. of Energy Region III, Appropriate Energy Technology, Small Grants Program. 1980.

165)Pullin, Roger S.V.; Ziad H. Shehadeh, Eds., Integrated Agriculture-Aquaculture Farming Systems. International Center For Living Aquatic Resources Management. May 1981.

166)Pyle, L. Dr.. "Costs and Benefits of Methane Generation in Poor Countries". Methane-Proceedings of a One-Day Seminar. Dr. Leo Pyle, Peter Fraenkle Eds. Intermediate Tech. Development Group. 1975.

167)-----, The Report of the Alcohol Fuels Policy Review. U.S. Dept. of Energy. June 1979.

168)-----,Road Map to Home Grown Energy. Rutan Publishing.

169)Roberts, Kenneth J.; Phillip F. Warnken, Kenneth C. Schneeberger. The Economics of Organic Crop Production in the Western Corn Belt. Ag. Econ. Paper No. 1979-6.

170)Ru-chen, Chen; Huang Cong, Xiao Zhi-ping. A Biogas Power Station in Foshan-Energy From Night Soil. Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences

171)Rutan, Al. "Al Rutan, The Methane Man". Alternative Sources of Energy. #37. May-June 1979.

172)Rhyther, John H.. Cultivation of Macroscopic Marine Algae and Freshwater Aquatic Weeds. Solar Energy Research Institute. Jan. 1980.

173)Ryther, J.H.; L.D. Williams, D.C. Kneale. A Fresh Water Waste-Recycling Aquaculture System. The Harper Branch Foundation Inc. 1977.

174)Schatz,Joel; Tom Bender. Cosmic Economics, Office of Energy Research and Planning, Office of the Gov. State of Oregon. March 1974.

175)Scheller, Dr. Wm. A.; Brian J. Mohr. Net Energy Analysis of Ethanol Production. Dept. of Chemical Engineering U. of Nrbraska, Lincoln 1976.

176)Scheller, Dr. Wm. A.; Brian J. More. Protein Concentrates From Distiller's By-Products. Dept. of Chemical Engineering, U. of Nebraska, Lincoln, 1975.

177)Scherff, J.L.. "Energy Use and Economics in the Manufacture of Fertilizers". Energy Agriculture and Waste Management Cornall Agricultural Waste Management. Conference. Wm. J. Jewell Ed. 1975.

178)Schulte, D.D.. A Study of Methane Production From Animal Wastes by Anaerobic Processes. Agriculture Canada, Dept. of Supplies and Services. 1977.

179)Scoll, Stephen. "Making Alcohol-Practical Aspects of a Fractional Distillation Column" Alternative Sources of Energy. March-April 1980.

180)Seshadri, C.V.. Analysis of Bioconversion Systems at the Village Level. World Hunger and Natural Resources Program of the U.N. University. Nov. 1978.

181)Seshadri, C.V.; Sebastian Thomas. Mass Culture of Spirulina Fusiformis Using Low Cost Methods. National Workshop on Algal Systems Proceedings, Oct. 1980.

182)Seshadri, C.V.; Sebastian Thomas. *Mass Culture of Spirulina Using Low Cost Nutrients.* Shri A.M.M. Muragappa Research Center Biotechnology Letters. 1979.

183)Seshadri, C.V. Sebastian Thomas, R. Manoharan, N. Jeeji Bai, G. Raja. *Mass Culture of Spirulina Fusiforms.* Shri A.M.M. Muragappa Chettiar Research Center. Oct. 1980.

184)Sheaffer, John R.; Patricia A. Ledford, Bernard C. Nagelvoort, J.David Mullan, Lee T. Rozaklis. *A Synergistic View of Anaerobic Digestion.* The Corporation for Public Private Ventures. May 1980.

185)Shelton, Jay; Andrew J. Shapiro. *The Woodburner's Encyclopedia.* Vermont Crossroads Press. 1976.

186)Short, T.H.; W.L. Baurle. "Greenhouse Production With Lower Fuel Costs" *Cutting Energy Costs-The1980 Yearbook of Agriculture.* Jack Hayes Ed. 1980.

187)Sievers, D.M.; J.R. Fischer, N.F. Meador, C.D. Fulhage, M.D. Shanklin. *Engineering and Economic Aspects of Farm Digesters.* American Society of Agricultural Engineers. Winter 1975.

188)Singh, Ram Bux. *Biogas Plant Generating Methane From Organic Wastes and Designs With Specifications.* Gobar Gas Research Station. March 1976.

189)Slane, Thomas C.; Robert L. Christensen, Cleve E. Willis, Robert G. Light.. *An Economic Analysis of Methane Generation.* Massachusetts Ag. Experiment Station, College of Food and Natural Resources, U. of Mass. at Amherst. Bulletin No. 618 Jan. 1975.

190)Slichter, Kathy. "Greenhouses Save Greenbacks". *Soft Energy Notes.* Jan.-Feb. 1982.

191)Smith, R.J.; J.A. Miranowski, R.L. Vetter. *Energy Relatioships for a 320 Acre Iowa Farm-An Attempt to Increase Production of Grain and Meat While Rendering The Farm Energy Self-Sufficient by Generating Methane Through Anaerobic Fermentation of Residues.* U.S. Dept. of Commerce, Agricultural Research Service, Hyattsville Md. August 1977.

192)-----, "BIOMASS" *Alternative Sources of Energy.* Jan.-Feb. 1981. (Staff)

193)-----, "BIOMASS" *Alternative Sources of Energy.* Jan.-Feb. 1982. (Staff)

194)Stein, Richard G.. *Architecture and Energy-Conserving Energy Through Rational Design.* Anchor Press/Doubleday 1978.

195)Steinhart, John J.; Carol E. Steinhart. "Energy Use in the U.S. Food System" *Science* Vol. 184. April 1974.

196)Stout, B.A.; C.A. Myers, A. Hurand, L.W. Faidley. *Energy For World Agriculture.* Food and Agriculture Organization of the U.N. 1980.

197)Strachota, Nancy; "BIOMASS". *Alternative Sources of Energy.* May-June 1981.

198)Subramanian, S.K.. *Biogas Systems and Sanitation in Developing Countries.* Oxfam with the Ross Institute of Tropical Hygeine. July 1977.

199)Sweeten, John M. compiler. *Methane Production From Livestock Manure.* Livestock Environmental Sciences Committee, Cattle Feeders Associations and Cooperative Extension Services Southern Great Plains States. 1978.

200)-----, Proceedings REACT '78-A Symposium on Economics of Renewable Energy and Energy Conservation Options. The Biomass Energy Institute. October 1978.

201)Thompson, Richard. "How Farmers Can Reduce Fertilizer Bills by Using Farm Wastes and Urban Sludge". Compost Science. May-June 1975.

202)Timbers, G.E.. Present Use of Energy on Canadian Farms. Engineering Research Service 1975.

203)Todd, Nancy Jack Ed.. The Book of the New Alchemists. The New Alchemy Institute. 1977.

204)Tsai, Pi-Hsin. Mass Culture and Utilization of Spirulina platensis on Fermented Hog Manure. Taipan Fish Culture Station-Taiwan Fisheries Research Institute. Oct. 1980

205)-----, Report ans Recommendations on Organic Farming. USDA Study Team on Organic Farming, U.S. Dept. of Agriculture. July 1980.

206)Vilstrup, Dick. "Less Energy, More Food, Part Two of Overview." Cutting Energy Costs-The 1980 Yearbook of Agriculture. Jack Hayes Ed.

207)Vollrath-Vaugh, Jean. Growth of Water Hyacinth on Digester Residues.(Unpublished Manuscript) March 1980.

208)Vollrath-Vaughn, Jean. Mass Production of the Algae Spirulina. (Unpublished Manuscript) March 1981.

209)Vollrath-Vaughn, Jean. Water Hyacinth-Stream Sanitation. (Unpublished Manuscript) 1981

210)Welsh,F.W.; D.D. Schulte, E.J. Kroeker, H.M. Lapp. The Effect of Anaerobic Digestion Upon Swinr Manure Odors. Canadian Society of Agricultural Engineering. July 1976.

211)Wen, Wu Dr.. Biogas Utilization in China. Proceedings Bioenergy 1980.

212)White, R.K.; D.L. Forster.. A Manual on Evaluation and Economic Analysis of Live-Stock Waste Management Systems. U.S. Environmental Protection Agency May 1978.

213)Whitman, Richard J.. "Energy Expenditure and Food Production". Compost Science Magazine. Sept.-Oct. 1974.

214)-----, Who's Squeezing the Consumer? What You Need to Know About Food Policy. National Consumer's League, National Family Farm Coalition.

215)Williams, D.W.; T.R. McCarty, W.W. Gunkel, D.R. Price, W.J. Jewell. "Energy Utilization on Beef Feedlots and Dairy Farms". Energy Agriculture And Waste Management Cornell Agricultural and Waste Management Conference. Wm. J. Jewell Ed.. 1975.

216)Williams, D.W. ; T.R. McCarty, C.R. Morris, W.W. Gunkel, D.R. Price. Utilization of Biogas for Farm Production Energy. American Society of Agricultural Engineers. Paper No. 75-1071.

217)Williams, Peter. Personal Correspondence

218)Wolverton, B.C.; Rebecca C. McDonald. Vascular Plants For Water Pollution Control and Renewable Sources of Energy. Proceedings Bioenergy. 1980

219)Wolverton, B.C.; R.C. McDonald, J.Gordon. Bioconversion of Water Hyacinths into Methane Gas. National Aeronautics and Space Administration. July 1975.

221) Wylie, Jim. "Greenhouse Vegetables in the North Country". Alternative Sources of Energy. #36 Feb.-March 1979.

222) Yanda, William. Solar Sustenance Project-Phase II Final Report. Proceedings-Conference on Energy Conserving Solar Heated Greenhouses, Marlboro, Vt. 1977.

223) Yang, P.Y.; C.J. Huang, K.K. Chan. Process Kinetics of Anaerobic Bioconversion for Semi-Solid Organic Wastewater. International Conference for Ag. Engineering in Natl. Development, Selangor, Maylasia. Sept. 1979.

224) Yang, P.Y.; C.J. Huang, H.M. Gitlin. Enhanced Energy Production and Water Reuse for Swine Operation in Hawaii. American and Canadian Societies of Agricultural Engineers. June 1979.

225) Yang, P.Y.; C.J. Huang, H.M. Gitlin, W.I. Hugh. Low-Cost, On-Site, and Effective Waste Management System for a 2000-Pig Farm in Hawaii. International Symposium on Biogas, Microalgae and Livestock Wastes. Sept. 1980.

226) Yang, P.Y.; C.J. Huang, C.C. Ho. Growth Kinetics of Mixed Microalgae With and Without Anaerobically Digested Swine Wastes. International Symposium on Biogas, Microalgae and Livestock Wastes. Sept. 1980.

227) Young, Robert J.. Nutritional Potential for Recycling Waste. Federation of American Societies for Experimental Biology. April 1973.

228) Zaltzman, Professor Raul; Dr. David Doner, Dr. R.C. Balie. "Perpetual Methane Recovery System" Compost Science. Summer 1974.

229) Ze-shu, Quian; Wu Jen-Ding. Studies of Observations on Methane Fermentation in the Farmyard Digesters in China. Dept. of Soils and Agricultural Chemistry, Zhejiang Agricultural University, Hangzhou, China.