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DEPARTMENT OF ENERGY PROGRAMS AND OBJECTIVES :

ENERGY CONSERVATION IN AGRICULTURIAL PRODUCTION

DECEMBER 1977

U.S. DEPARTMENT OF ENERGY
DIVISION OF INDUSTRIAL ENERGY CONSERVATION

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DOE/CS-0004
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DEPARTMENT OF ENERGY PROGRAMS AND OBJECTIVES: ENERGY CONSERVATION IN AGRICULTURAL PRODUCTION

DECEMBER 1977

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Under Contract No. 31-109-38-3896

For The
U.S. DEPARTMENT OF ENERGY
DIVISION OF INDUSTRIAL ENERGY CONSERVATION
WASHINGTON, D.C. 20545

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ACKNOWLEDGEMENT

The technical assistance in the preparation of this publication was provided by the Washington Scientific Marketing, Inc., Washington, D.C. under Argonne National Laboratory Subcontract No. 31-109-38-3896.

Department of Energy
Washington, D.C. 20545

November, 1977

To the reader:

This document describes the current Department of Energy (DOE) agriculture research program as it relates to the research recommendations submitted by a 1976 workshop on energy conservation in agricultural production. It is intended to reflect the DOE Division of Industrial Energy Conservation response to the ideas and concerns of the agriculture sector as expressed by the workshop participants.

The format of this document is based on the generic research programs of the Department. The project recommendations of the workshop are refered to by project number in parentheses within this response document. The reader is therefore urged to refer to the Report of the Proceedings as an accompaniment to fully appreciate the context of DOE's responses.

Preparation of this report necessitated a thorough internal review and evaluation of the Agriculture program objectives and activities to ascertain whether and how the workshop recommendations have been addressed. It is hoped that similar discussions will be stimulated among the readers.

This report has been prepared and edited by Washington Scientific Marketing, Inc. in close cooperation with the Division of Industrial Energy Conservation, and in particular with the Agricultural and Food Systems Branch.

Sincerely,

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*Report of the Proceedings of the Energy Research and Development Administration Workshop on Energy Conservation in Agricultural Production, July 15-16, 1977, Washington, D.C., available from the National Technical Information Service, Springfield, VA 22161, #CONF-760736 ($5.50).

Department of Energy Programs and Objective: Energy Conservation in Agricultural Production

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Department of Energy Programs & Objectives: Energy Conservation in Agricultural Production

Introduction

A Workshop on Energy Conservation in Agricultural Production was sponsored by the Energy Research and Development Administration (now integrated into the Department of Energy) in July 1976. The purpose of this meeting was to bring together Agricultural Engineers, Scientists, Economists and Producers from both the private and public sectors to identify opportunities for energy conservation research, development, and demonstration (RD&D). The 55 participants identified 110 RD&D projects which they felt ERDA should consider in its research and development program.

In the period between the workshop and the establishment of the Department of Energy (DOE), the Division of Industrial Energy Conservation has used the recommendations of the workshop to formulate their fiscal year 1978 budget and to coordinate its research program with the Department of Agriculture.

This response document has been prepared as one segment in the Division's effort to inform persons working in agriculture and its support industries of the programs and projects the Division and other segments of the Federal energy establishment have undertaken. This report has also been prepared as a part of an intensive review of the Division's Agriculture program to describe how and where the workshop project ideas have been incorporated into the Division's ongoing research program.

A second workshop on Energy Conservation in Agricultural Production was held on October 31 and November 1. The purpose of this meeting was to: (1) evaluate and refine some of the ideas that were submitted in the first workshop, (2) make a priority listing of RD&D projects based on their energy savings and potential for adoption, and (3) submit comments and criticisms on the present Division program.

The 1976 workshop, this reponse document, and the second workshop meeting have been undertaken to coordinate dialogue between the Division and its industrial and agricultural constituency. Maximization of private sector involvement in the conduct, review, and evaluation of the federal energy RD&D program is a primary Division objective and the success of the industrial program hinges critically upon its fulfillment. The workshop and follow-up activities provide a forum for

defining the optimal federal role and for the exchange of information about ongoing efforts in both the private and public sectors, and lay groundwork for eventual technology transfer.

While reading the workshop recommendations and the corresponding DOE programs, it should be borne in mind that the major thrust of the DOE Industrial Energy Conservation program is to demonstrate technologies that:

- Industry would not pursue on its own primarily because of the high risks involved.
- Have high potential benefit in terms of energy savings.
- Significantly accelerate energy savings.
- Promise significant savings in fragmented industries which have no research funds allocated to such effort.
- Have a return on investment which, once developed, will sufficiently attract broad scale implementation.
- Are cost-shared by the industries affected.
- Are environmentally acceptable, operationally safe, and reliable.

The Division is refining a computer model which processes specific project-related data (capital cost, operating cost, useful life, year of introduction, total market, etc.) and provides a summary ranking of project ideas. This threshold criteria technique is being used as a guideline to judgement and, since the technique does not take all related considerations into account (for example, the substitution of inexhaustable fuels for natural gas), there will be exceptions taken, i.e. projects may be supported which have received a relatively low threshold criteria ranking, but which have other critical values that dictate implementation. Systems studies, for example, do not yield energy savings per se, but are often considered priority projects to identify promising conservation RD&D opportunities.

The reader may also wish to refer to the DOE Industrial Energy Conservation Management Control & Review Document (MCRD) which describes the objectives and activities of all the Division's programs including those of the Agricultural and Food Systems Branch upon which this report is in part based. The FY 78 edition of the PAD will be avialable shortly from the DOE Technical Information Center, PO Box 62, Oak Ridge, TN 37830.

Overview of the DOE Division of Industrial Energy Conservation Program

The baseline goal of the Division of Industrial Energy Conservation is to improve technology which will make industry and agriculture more energy efficient. The Division is working to remove technological and economic barriers so that industry and agriculture will adopt more energy efficient processes and technology. The Division has adopted two program strategies to achieve this goal:

- Horizontal thrust strategy - These programs apply to a large range of industries and consider areas such as waste energy reduction and alternate materials utilization.
- Vertical thrust strategy - These programs apply to industry specific processes.

There are six programs being undertaken by the Division:

- Waste Energy Reduction
- Advanced Cogeneration
- Alternate Materials Utilization
- Industrial Process Efficiency
- Agricultural & Food Process Efficiency
- Program Development & Analysis

The first three programs address the horizontal thrust strategy. The following two programs address the vertical thrust strategy. The final program serves to assist the Division's program planning, program management, and technology transfer efforts.

The Agricultural and Food Process Efficiency Program's mandate is to promote advances in technology for producing and processing food. Since the agricultural and food processing industry is fragmented, dependent on high quality fuels (i.e. natural gas), and lacks the facilities for energy conservation RD&D, the Division has focused its efforts in five task areas:

- Fertilizer production - The Division is presently working with TVA's National Fertilizer Development Center to develop new formulations for fertilizer granulation. The goal of the present and future research efforts sponsored by the Division is to develop and demonstrate technology that will reduce the consumption of natural gas in the manufacture

of ammonia-based fertilizers.

- Irrigation Systems - The objective of this program is to develop and demonstrate more energy efficient crop irrigations systems. The Division has made a solicitation for proposals which would support the design, development, and demonstration of energy conservative irrigation systems. These proposals are now under consideration by the Division.

- Energy Integrated Farm Systems - This program is currently under development by the Division. The objective of this program is to develop technologies and equipment which would minimize the outside energy dependence of the farm by utilizing agricultural by-products. A systems approach will be implemented in this program so that the tradeoffs can be identified and the use of by-products can be optimized.

- Food Process Systems Analysis - This program seeks to study methods to integrate energy conservative technologies in food processing. One aspect of this effort is the development of the AGRIMOD computer model of agricultural production, food processing, and food distribution. The system will assist in identifying where energy conservative technologies will have a significant impact, analyze the impacts, and analyze the effect of government policies which would hasten the adoption of these technologies.

- Food, Feed, and Grain Preservation - This program studies energy saving alternatives to present methods of food and grain preservation. Work is presently addressing: heat pump grain drying, aseptically packaged sterile milk, and the preservation of fresh foods by gas exchange. There are a number of other projects which are described in the body of the report.

The Division has been aware for some time of the potential conflict and duplication between its programs and the programs of other agencies of the Federal Government. For that reason the Division has engaged in a Memorandum Of Understanding with the Department of Agriculture to develop a national plan for energy conservation research, development, and demonstration in the agricultural sector. The Division also meets with representatives of EPA to coordinate their research programs. Finally, the Division is working closely with other Division's in the Department of Energy so that the research programs of each will compliment one another.

DEPARTMENT OF ENERGY

DIVISION OF INDUSTRIAL ENERGY CONSERVATION

PROGRAMS AND RESPONSES TO WORKSHOP RECOMMENDATIONS

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FERTILIZERS

The Division of Industrial Energy Conservation is planning to support conservation research, development and demonstration on nitrogen fertilizer production. Details on the scope and funding level of this program will be set forth in a competitive procurement announcement expected to be released early in 1978 (notification will appear in the Commerce Business Daily). The total energy requirement for fertilizer production in the United States is about 6.2×10^{14} BTU's, with nitrogen materials consuming 85%. This far exceeds any other agricultural operation in energy intensity. Almost all U.S. ammonia production is based on the use of natural gas in the classic Haber process as a feedstock and heat source. High application rates of nitrogen fertilizers are common to insure maximum productivity and to minimize labor costs. The development of improved technology for the production, distribution, and utilization of nitrogen fertilizer resources can result in a significant reduction in energy requirement for the production of agricultural crops.

DOE wishes to encourage and participate (through cost-sharing contracts) in the development of new technologies that will accomplish this reduction in energy usage and dependence upon premium fuels. This could include, for example, development of systems using alternates to natural gas as a feedstock (such as direct production from coal, production of hydrogen for the Haber process by electrolysis of water, and direct nitrogen fixation from air). Research and demonstrations leading to the reduction in fertilizer consumption by agricultural crops through optimum scheduling, placement, use of slow release materials, and improved instrumentation for monitoring crop needs would also be of interest. The National Fertilizer Development Center of the Tennessee Valley Authority is investing some $40 million in a demonstration ammonia plant using coal gas as a feedstock. Parts of the above DOE program may tie into or supplement this effort.

The Division has one project underway in the agricultural chemicals sector. The National Fertilizer Development Center is investigating processes for conserving energy in the production of fertilizers in ammoniation-granulation plants under an Interagency Agreement initiated in FY76. This 4-year project will develop new formulations which reduce moisture added in the granulation process, and utilize chemical heat-of-reaction generated by combinations of ammonia and phosphoric acid as a substitute for natural gas in drying granular fertilizer. It is estimated that fuel consumption in these plants can be cut by as much as 65% using the new formulation procedures, resulting in a cumulative energy savings of 5.8

million barrels equivalent by 1985 with first savings occuring in 1979. TVA is currently refining a pipe-cross reactor and other melt-type processes, and collecting data from ammoniation-granulation plants on energy requirements for producing fertilizers by conventional processes. Performance tests on the new formulations will be conducted in pilot plants during FY78, and demonstrations in commercial plants under actual operating conditions are planned for FY79. This promising effort has generated a great deal of interest in the industry.

The workshop had a lively discussion on the possibilities for agricultural utilization of non-agricultural by-products (10). DOE agrees that this concept needs to be more fully evaluated, and may sponsor some feasibility studies in the future. In the early 1970's, costs of fertilizers rose more rapidly than costs of fuel and labor. If this pattern continues in the future, animal manures and sewage sludges will be regarded increasingly as substances that are valuable for crop production and less frequently as wastes that are to be disposed of in the most economical manner. In the meantime, industrial wastes which contain quantities of essential plant nutrients or could serve to reduce energy consumed in the production of fertilizers (such as stack gases) should be identified and characterized with respect to location, frequency, chemical composition and uniformity, etc. Major obstacles such as transportation, economics, energy-intensive handling, and concentrations of heavy metals and other toxic substances should be assessed. The potential applicability of these wastes to processes within their industries, to other industries, and to agricultural operations should be carefully studied so that their use is optimized regarding economics and energy. DOE's program on Fuels from Biomass, which is concerned with generating clean fuels from animal and crop residues, is described in the Waste Heat and Alternate Fuels section of this report.

One of the recommendations from the 1976 Agricultural Production workshop dealt with increasing the efficiency of nutrient utilization, citing several specific areas for research (12). Since considerable information along these lines has evolved at land grant institutions and USDA over the years, it was advised that USDA draw the bits and pieces together into a single comprehensive source on fertilizer management which would delineate the current state-of-knowledge on application techniques and timing, productivity, and energy considerations for all major crops and regions.

Biological nitrogen fixation was also discussed as an important way to influence energy requirements for fertilizer. The USDA/ARS has an active research program to improve the capability and efficiency of symbiotic nitrogen-producing plants

and to improve their genetic and biological characteristics. A longer range part of this effort is concerned with developing the capability in wheat, corn, and other nonleguminous crops.

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IRRIGATION

The concerns and recommendations of the Water Resources group at ERDA's 1976 Agricultural Production workshop (Projects 70 through 92) were reviewed with interest by the Division, and used as informal guidelines in formulating a competitive solicitation for irrigation-related proposals. Large quantities of crude oil and natural gas are used for the pumping of irrigation water to food crops throughout the arid and semi-arid regions of the nation. Improved technologies for the pumping, distribution, and utilization of water resources can result in a significantly reduced energy requirement. Therefore, encouragement and participation in the development of new or improved technologies that will yield greater efficiencies in irrigation pumping plants, irrigation system designs, and improved water management while maintaining high levels of agricultural productivity, is considered a top priority within the Division of Industrial Energy Conservation.

The primary interest of the Division at this time is to evaluate and consider for support energy-conserving design, development, and commercial demonstrations. A Program Opportunity Notice (PON) has been issued (notification appeared in the Commerce Business Daily June 24, 1977; closing date for receipt of proposals was October 5, 1977) which describes the Division's interest in the following:

1. irrigation pumps that are more efficient than conventional pumps (under conditions experienced in the field);

2. irrigation wells that have minimum drawdown (difference between static water level and the dynamic pumping water level) head at rated pumping capacity;

3. sprinkler systems that operate effectively (good water distribution) at pressures significantly lower than conventional systems;

4. irrigation water distribution systems that reduce irrigation pumping energy requirements by improved water application efficiency (less water pumped as a result of more uniform application and/or reduced evaporation and percolation losses);

5. methods for significantly improving irrigation pump prime mover efficiency; and

6. energy efficient irrigation systems using systems design and optimization techniques.

Examples of the type of projects that will be considered for funding include, but are not limited to: development of deep well pumps exhibiting improved efficiencies; design and demonstration of irrigation power plants exhibiting improved mechanical efficiencies through the use of Rankine bottoming cycles or other techniques; development and demonstration of systems for reducing pumping pressures required to distribute water to the crop; research and demonstrations leading to reduction in water consumption by agricultural crops through optimum water scheduling; and improved instrumentation for monitoring crop water needs.

It is anticipated that multiple research awards will result from this solicitation. Work will be initiated in winter, 1977, with industrial demonstrations scheduled for 1978.

An evaluation and comparision of energy requirements for irrigation pumping systems using alternate enery sources has been sponsored by the Division at Kansas State University, and a final report should be available early in 1978. The study computed the costs per unit of water delivered to selected crops via systems utilizing alternate energy sources for a standardized well. Also, a national profile of energy requirements for driving pumps has been compiled by DOE's Division of Conservation Research and Technology, which focused on centrifugal irrigation pumps and considered methods for improving their efficiency.

Irrigation conservation suggestions and cost examples are contained in a new series of FEA/USDA publications designed for growers: Guide to Energy Savings for the Vegetable Producer, For the Field Crops Producer, and For the Orchard Grower. Pumping plant efficiencies, reduced water application, re-use of runoff water, irrigation system design improvements, and equipment maintenance are among the energy-saving ideas discussed.

DOE's Division of Solar Energy is involved in design and demonstration of solar-powered irrigation systems. That Division's two objectives are: (1) the development of technology which will result in practical and economical designs, and (2) the identification and assessment of market requirements so solar-powered systems can become practical alternatives to conventional irrigation power sources. The program involves a series of experimental projects to examine the variety of design concepts required to satisfy the range of national applications; development of systems designs with the highest maintenance-free performance per unit cost; analytical studies to identify and

evaluate potential applications; analysis of market potential; and development of a plan with industry for the commercialization of solar irrigation.

A major project, a joint effort of DOE and the State of New Mexico, is an experimental solar-powered system designed to pump enough water to irrigate 100 acres of mixed crops and also support such things as a greenhouse and fish farm. The demonstration in New Mexico's Estancia Valley was initiated with the 1977 growing season, and a series of international workshops on solar irrigation will be conducted over the next several years to share experiences and results. Planning and design work is underway to determine how to best utilize the off-season energy, and to upgrade the facility to power a low energy center pivot system. Other efforts include construction of a shallow well model, and design studies on a deep well experiment to be located in Arizona.

DOE is also sponsoring demonstration of the nation's first crop irrigation system to be powered by solar (photovoltaic) cells, which convert sunlight directly into electricity. This project is being conducted by the Massachusetts Institute of Technology and the University of Nebraska - Lincoln, near Mead, Nebraska. The photovoltaic cells will drive a pump to irrigate 80 acres of corn and soybeans, and off-peak electricity will be used at night to refill the reservoir. During the fall and winter months the system will be used to dry corn harvested from the field. DOE's photovoltaic cell program is aimed at bringing down their price to competitive levels by 1986; at current prices, solar cells are far too expensive for use in irrigation and grain drying except on an experimental basis.

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CROP DRYING

Several crop drying research alternatives were discussed at the workshop, and many are being addressed by the DOE Agriculture program. This is an area of high conservation priority, since these operations are relatively energy-intensive and critically dependent upon diminishing fuel supplies.

The recommendation on heat recovery systems for crop dryers has good potential (59). Most heated air crop dryers have thermal efficiencies of about 50%, and previous research and demonstration efforts indicate that significant energy savings can be attained. It appears possible to cut the energy loss by 50% in a high temperature grain dryer by recycling half the exhaust heat and still have a reasonable payback on the higher initial investment. Development of new viable designs with improved control systems for waste heat recovery systems should be intensified.

Evaluation of the technical and economic feasibility of heat pumps for grain drying (63) is planned. Westinghouse Electric Corporation has done extensive preliminary work on state-of-the-art heat pump grain drying, in cooperation with Purdue University and Farm Fans, Inc. DOE intends to continue this effort with field testing of a low speed batch apparatus, testing of medium and high speed systems, and ultimately a closed-system unit. This effort includes study of the suitability of using heat pumps for all grain dryer types; comparative analysis of heat pump economics versus fossil fuels, natural drying, chemical drying, solar systems, and Joule resistance heating; demonstration of full scale heat pump grain dryers, and an examination of the effect of broad heat pump usage on electrical generation and distribution capacity. Heat pumps can be employed in multiple uses on the farm, and this potential can be developed to alleviate its relatively high cost for short time annual grain drying operations. Although experimentation with heat pumps for grain drying has been of interest for the past two decades and some systems are in use today, the concept has become a more attractive candidate for refinement and demonstration in view of rapidly rising energy costs and the possible shortage of LP gas.

The Division has received and is presently evaluating several proposals regarding development and demonstration of dryeration (67). This method has generally been proven to be safe and effective, although additional study of condensation and other problems may be necessary for some crops. Dryeration has been most widely adopted in the rice belt, and its significant energy savings, increased drying capacity, and improved grain quality from reduction in stress cracks has

been documented. However, due to the capital investment required for the bins and perceived risk of the technique in areas where it is not known and demonstrated, a coordinated promotion and demonstration program is being considered, possibly in connection with combination drying. The need and importance of additional specific research will be identified in DOE's evaluation of previous and proposed dryeration projects.

The workshop discussed research on low temperature grain drying (60). Deterioration of corn as related to time and temperature is reasonably well established, but low temperature drying research is needed on other grains and crops. DOE is interested in fostering a broader base of crop-specific information and technical/engineering knowledge, including off-peak operation, so that eventually a drying handbook covering the spectrum of crops, weather regions and technologies could be compiled.

DOE's Division of Solar Energy is very active in grain and crop drying R&D; its projects are managed by the Agricultural Research Service and the Cooperative State Research Service of USDA and the State Agricultural Experiment Stations. Current efforts include: development and testing of solar collectors especially designed for low temperature grain drying; study of the effectiveness of eutectic salt solution as a heat storage medium for solar energy used in corn drying; comparison of solar drying for wheat with in-bin drying using unheated air and natural drying in the field; and solar supplementation of a heat pump for a low temperature bin drying system for corn. Solar experiments are underway on peanut drying and curing, curing of burley tobacco, and drying of forages (hay, alfalfa, and grass).

A study of the use of preservatives to delay drying was proposed (66). This type of research, although apparently of considerable interest to agricultural chemical firms, is not considered a priority in DOE's Agricultural program, for several reasons. A study to ascertain whether chemical treatment actually requires less energy than conventional drying techniques would be necessary before any more specific research opportunities could be evaluated, since the preservatives usually are petroleum-based (propionic acid) and costly to produce (such as ammonia). Imperfections of current applicators, heat transfer problems in large bins, and the complexities that would be involved in surmounting EPA regulations which prohibit the processing of treated grains off the farm suggest that a great deal of research money and time is required to achieve an indeterminate (and probably small) savings. Some preliminary experiments have been conducted at land grant universities to outline time, temperature, and

chemical treatment levels for hay, rice, and corn feed, but more precise definitions of these parameters and the acid capabilities is needed before the concept can be considered "proven".

The workshop urged DOE to consider innovative, "revolutionary" longer range drying technologies as well as the more conventional methods in its research funding plans (61). The Department has undertaken, as was recommended, a study of microwave-vacuum drying by McDonnell Douglas. A small package batch unit (7.5 bushels per hour for 5 points of moisture removal) consisting of a microwave system, vacuum chamber, condenser, and product handling system is being installed at the USDA/ARS Laboratory in Tifton, Georgia. Extensive USDA tests are planned to determine the optimal range of conditions and control parameters for a variety of crops (corn, peanuts, etc.). Even though this technique is capable of producing a very high quality grain and cuts down on anaphylatoxins, feasibility and cost/benefit evaluations conducted last year indicate that the energy savings of the so-called MIVAC dryers are not sufficiently large to offset their high initial cost, compared to less expensive existing methods. The technique also appears to be more energy-expensive than previously thought. DOE has accordingly de-emphasized the research and significantly reduced its role in underwriting the effort.

Another effort which falls into this "innovative" category is a Lockheed feasibility study and development of a solar-regenerated desiccant crop drying facility for DOE's Divisions of Solar Energy and Energy Storage Systems. The desiccant dryer is comprised of three main elements: an absorption loop in which moist air from the crop bin is de-humidified by the liquid desiccant and dry air is supplied to the bin (closed cycle chemical drying); a regeneration loop to remove the water which was added to the desiccant but retains its heat of condensation; and a desiccant storage tank. The energy source may be either solar, fossil, or a combination of both. The heart of the system is the regeneration loop, which uses heat at 200-270^{o}F to regenerate (remove water from) the dilute desiccant and delivers a lower grade heat which can be used for either open-cycle thermal drying or can be furnished as process heat for a non-drying uses. The only heat rejected from this cyclic process is that used for open-cycle drying (30-40% of total drying capacity) or the process heat option. Previous characterization of both solid and liquid desiccants pointed to an aqueous solution of lithium chloride as the most attractive. Although it is more expensive than others, it has favorable physical properties and is particularly effective for drying delicate crops such as seed corn, peanuts, soybeans and rice.

Testing and evaluation of the bench-scale demonstration equipment (completed April, 1977) concluded that the regenerated desiccant crop drying concept is technically viable and has the capability to achieve a drying efficiency of approximately twice that of conventional drying systems. When using a fossil fuel energy source, energy savings are projected at about 40-50%. With solar energy input, the total fossil fuel savings could be 70-90%. Because the installed cost of this new equipment appears to be considerably higher than conventional apparatus, refinement of the desiccant regeneration subsystem to improve its heat and mass transfer efficiencies is needed to reduce size and cost. Regarding applications, the system, with or without the use of solar heat, will be best suited for a large central processing operation where it can receive a maximum annual amount of use and will benefit from economies-of-scale.

The Division of Industrial Energy Conservation is interested in exploring other novel crop drying ideas which are beyond the horizon of the present state-of-the-art as an adjunct to its nearer term research objectives.

The concept of using industrial waste heat for agricultural applications has recently been viewed more seriously because of increasing energy costs. The workshop participants suggested that the idea be pursued in connection with crop drying (68). American industry accounts for more than 40% of the nation's total energy consumption, and rejects approximately 40% of its required energy input in the form of waste heat. Recovery and utilization of waste heat is now a primary consideration for all plant managers, and a variety of schemes for cascading, or sharing heat among industries are being studied. DOE's Agriculture program would be interested in pursuing a systems study to assess the potential as well as barriers foreseen with respect to using industrial waste heat to provide energy for a variety of farm operations. The cost and practicality of transporting grain to and from a dryer located in proximity to a power plant may severely limit practicability of this concept. The value of this energy source for forage drying would be even more limited because drying with heated air is less necessary and transportation is more difficult. One exception might be utilization of heat from power plants for dehydration of crops in large quantities for use as commercial feeds. An important part of a systems study on the entire subject would be to develop a hierarchy of uses for the waste heat available for crop drying and other agricultural operations, which would rank alternatives according to their feasibilities and cost effectiveness. This would take into account other attractive ideas such as using power or steel plant waste streams in the production of nitrogen fertilizers. Regarding crop drying, the conclusion would likely be that the applicability of

industrial waste heat is restricted to large scale grain production in the immediate vicinity of the waste heat source, but hopefully a continuum of agricultural opportunities would be identified.

DOE's Division of Conservation Research and Technology is evaluating a number of low temperature heat utilization system concepts such as a combined energy production, agricultural production, and waste disposal community. Paper studies are underway on the potential for using waste streams from gaseous diffusion and conventional power plants to provide heat for industry (direct process use, boiler feedwater preheating, and as a heat source for an industrial heat pump) and agriculture (greenhouses, animal rearing facilities, aquaculture and soil heating). This program is described in the Waste Heat and Alternate Fuels section of this report.

Investigation of the technical and economic feasibility of coal-fired grain dryers was a subject of considerable interest at the workshop (62). This recommendation has been echoed by several prominent crop drying researchers. Farmers are concerned about the availability of gas and oil in sufficient quantities when they need it to preserve their crops. DOE agrees that a systematic evaluation of technological and economic (and environmental) factors is needed to address such broad questions as whether coal would be better converted to electricity at the power plant, since many crop drying and other farm operations already use this form of energy.

Development of a direct oil-fired burner for crop drying was suggested (64). Direct oil-fired burners on crop dryers are on the market and have been used for many years. They are very well developed and fairly clean-burning with no serious combustion residual problems. Hence, Federal research support is not needed.

Another alternate fuel recommendation includes the design of a gasifier or burner to utilize crop residues for on-farm crop drying (58). DOE would be interested in a review of the economics and technologies involved to determine where the most viable conservation opportunities are, and under what conditions they would be most readily adopted (farm size, capital intensity, etc.). This type of research could have good pay-off if conventional energy sources are not available at reasonable prices in the future.

DOE's Fuels from Biomass program is also interested in feasible concepts for conversion of animal and crop residues to clean fuels, although direct combustion is not regarded as having much potential relative to other thermochemical

conversion methods such as gasification and liquefaction, or to bioconversion. Direct burning of biomass poses several problems. Labor costs are high compared to the automatic stoking of uniform material, and air cannot be distributed well to achieve burning. Many coal or oil-fired units could be converted to burning of wood or other biomass if uniform biomass materials were provided. Although direct burning is financially attractive in certain locations over the short term, it may become less attractive when new biomass energy technologies are available.

FUEL SUBSTITUTION

The most popular topic at the workshop was alternate fuels for agricultural operations. The participants discussed R&D needs on animal and crop residues, industrial waste heat, coal, solar and wind applications to replace or supplement premium fuels and alleviate the critical dependence upon these energy forms for fertilizers, irrigation, crop drying, and water heating. DOE is supporting development of these technologies to establish their feasibility and help lower their costs.

Utilization of Agricultural Residues

The Agriculture program in the Division of Industrial Energy Conservation is interested in exploring the many possibilities for utilizing agricultural residues to power on-farm operations such as crop drying, irrigation or water heating on dairy farms. Information and experience gained in the Fuels from Biomass program (which will be detailed later in this section) will be utilized so that the full range of opportunities for biomass conversion will considered. The Agriculture program will probably not pursue in-depth research on particular bioconversion processes. The focus will be on technologies and equipment needing demonstration in animal and crop production systems which enable residues to be utilized for fuel, feed and fertilizer on-site. There are no immediate plans to incorporate off-farm projects because of the poor transportation economics substantiated in preliminary feasibility studies (16, 93, 98).

Overall, the Division of Industrial Energy Conservation would like to foster R&D that can contribute to realization of the energy-integrated, or energy self-sufficient farm concept. Demonstrations will likely be an important part of the program, since many technologies which have been laboratory-tested or applied in various industrial processes need only to be adapted and proven economical for agriculture. Some of the workshop recommendations of interest might be: define and demonstrate gas-generating systems for farm use (99); develop harvesting machines for grains which provide residues in collected state for conversion (95); utilization of the CO_2 conversion by-product (103); demonstration of direct combustion of field crop residues for crop drying (97).

The specifics of the program - priorities, funding levels, etc. - have not been drafted. It is anticipated that these objectives will be defined within the next few months so that the program can begin in FY 1978. The plans will be carefully coordinated with basic research efforts and feedlot projects

in the Fuels from Biomass program and with relevant programs at universities and USDA on soil nutrients and genetic-biological aspects (9, 108).

DOE's Office of Energy Technology has an extensive Fuels from Biomass program to investigate and demonstrate utilization of agricultural, forest, and animal residues to produce clean fuel products and petrochemicals. Inventories of resources, research on conversion processes, and studies of agricultural, environmental and societal impacts are underway. The program seeks to match biomass sources with appropriate conversion technologies with regard to economics of collection, production and distribution. Program areas are summarized below:

BIOCONVERSION PROCESSES

ANAEROBIC DIGESTION	-	SYNTHETIC NATURAL GAS (SNG)
FERMENTATION	-	ALCOHOLS AND PETROCHEMICALS
BIOPHOTOLYSIS	-	HYDROGEN

THERMOCHEMICAL CONVERSION PROCESSES

LIQUEFACTION	-	FUEL OILS
GASIFICATION AND PYROLYSIS	-	SNG, LOW AND MEDIUM BTU GAS
DIRECT COMBUSTION	-	ELECTRICITY AND PROCESS HEAT

PHOTOCHEMICAL CONVERSION

PHOTOELECTROLYSIS (WATER SPLITTING)	-	HYDROGEN

The workshop discussed the need for quantifying and characterizing available residues (94). The Stanford Research Institute has conducted an evaluation of the use of agricultural residues as an energy feedstock in the DOE Biomass program. The first nation-wide inventory of residues (manures, farm field crops and forestry in 3,000 counties) and their uses (feed, fuel, waste, etc.) has been compiled. Systems studies, production and conversion of sugar cane, sweet sorghum and sugar beets, grains and grasses, and silviculture energy plantations have also been completed.

On-site tests and economic analyses are in progress for feedlots which use manure as a feedstock and generate methane

or fuel, carbon dioxide for refrigerant, and a high protein residual suitable as an animal food supplement or fertilizer. A pilot plant to convert 40 dry tons/day of animal residues from a concrete feedlot for approximately 300,000 CF/day SNG is under consideration. Supporting R&D projects are underway on innovative concepts, small digestors, digestor kinetics, and pretreatment (such as heating to increse biodegradability), post-treatment and digestion alternatives. Another major program thrust is field experimentation and systems studies on fresh water and marine algae and brown kelp. Fermentation is another area of research, including some work on a unique anaerobic fermentation system design which has potential for operation with the simplest of demands on the farm. Enzymatic hydrolysis of cellulose (cattle feedlot wastes) and anaerobic fermentation to produce acetone and butanol is being studied. Competitive solicitation for a process development unit is scheduled for FY 1978.

Regarding thermochemical processes, operations are starting up at a liquefaction pilot plant to convert wood wastes to heavy fuel oil in Albany, Oregon. Other biomass feedstocks will be investigated at this facility, also. Bench-scale R&D projects are underway on catalytic gasification and pyrolysis of clean biomass feedstocks as opposed to waste technology (garbage feedstocks) and coal gasification. A plant is being designed for direct combustion of forest products to produce electricity. Although direct burning of biomass will contribute to the short term energy needs of the nation, its long range prospects appear overshadowed by other energy technologies. Consequently, direct combustion is given a lower priority than the conversion of biomass to fuels.

The Fuels from Biomass program is oriented to relatively large conversion facilities located close to growing sites in order to limit transportation costs and achieve economies of scale, rather than individual household and farming units. "Farm for Fuels" are envisioned where the biomass output in its entirety is guaranteed to an adjacent conversion plant, which in turn would sell and distribute its products to industries for fuel or feedstocks. Many of the workshop recommendations are being directly or indirectly addressed, particularly those dealing with animal residues which were an early focus of R&D because of the ease of collection on feedlots (24, 104, 106, 107, 110). Also, the in-depth basic research on specific handling and bioconversion processes for terrestrial cellulosic materials addresses other suggestions submitted to DOE (100, 101, 102). Genetic selection studies, which are planned in the near future, will concentrate on increasing the total biomass, not necessarily maintaining or increasing edible yield (96). No smaller on-farm projects or

demonstrations of conversion of crop residues off the farm are foreseen in the Fuels from Biomass program.

Waste Heat

Participants at the workshop were interested in the possibilities for using waste heat from industrial and power plants in agricultural operations (28, 38, 45, 68). DOE's Division of Conservation Research and Technology is working to define the array of low temperature waste heat sources and to develop the needed technology base in low temperature heat engines. A study has been completed, for example, to assess the economic feasibility of using reject heat from gaseous diffusion plants in several agricultural and industrial applications. The costs of using the heat off-site of a gaseous diffusion plant at temperatures of 90°F and 140°F were compared to conventional gas and oil systems. Among the agricultural processes considered, it was found that the use of waste heat is most favored for aquaculture - both open systems that use the condenser water directly in the heat utilization system and closed systems employing a heat exchanger to separate the two water streams. This is followed by greenhouses using evaporative pad systems, soil heating, greenhouses with dry heat exchangers, and animal rearing facilities.

A study conducted for DOE by the Oak Ridge National Laboratory, the Tennessee Valley Authority and the University of Tennessee to determine the feasibility of using waste heat for seasonal agriculture or aquaculture has concluded that only a relatively small percentage of the recovered heat could be put to economic use. Consequently, the viability of utilizing this reject heat will depend primarily upon the development of economic heat conversion systems and on-site applications such as space heating and power recovery. Currently, there is no heat cycle technology base for low temperature (less than 200°F), high efficiency conversion machines. Concepts under consideration include a nitinol solid state converter, an elastomer-powered converter, and a pressure-retarded osmosis converter. Design and development studies to address this problem will be initiated in FY 1978 to provided the needed technology in support of waste heat recovery systems such as that envisioned for the recovery of waste heat from DOE-operated gaseous diffusion plants, planned for 1982. It is possible that a combined energy production, agricultural production, and waste disposal system will be a major federal demonstration project at that time.

Coal

The workshop recommended that the DOE Agriculture program consider supporting the development of coal-fired grain dryers (62) and a coal-fired steam turbine (76). A preliminary study would be needed to ascertain technical, economic and pollution parameters before this type of proposal could be actively considered.

Solar, Wind, Fuel Cells

DOE's Office of Energy Technology has several programs to develop and demonstrate the use of solar technology to power agricultural operations. These programs are described in the following sections of this report; Crop Drying, Greenhouses, and Animal and Dairy Production Systems.

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CROP PRODUCTION SYSTEMS

The priority recommendation submitted by the workshop regarding crop production was that a systems approach be developed for energy conservation in agriculture. The participants suggested that energy flow models be employed to identify the impact of various management strategies, technological changes, energy/cost trade-offs, and gaps in knowledge throughout the production process. The complexity of interrelationships affecting the food system, and DOE's need to analyze and formulate agricultural energy research programs dictate the need for such a model.

The AGRIMOD dynamic simulation of the U.S. food production system which was developed and validated by Systems Control, Inc. under previous National Science Foundation sponsorship is being refined and enhanced with DOE's support. Its design provides a framework for analyzing the effects of national energy and conservation policies on the domestic food supply and on exports, for identifying the impacts of energy and resource constraints on production and prices, and for assessing the changes that may occur as a result of technological developments.

Currently, the AGRIMOD capabilities are being increased for carrying out energy policy analysis of the impacts of alternative energy conservation and research strategies on agriculture and the food industries so that it can assist DOE in evaluating the viability of proposed energy-conserving technologies. The system includes supply/demand, energy/cost, and input/output models of the fertilizer industry; farmers' planned resource allocation; livestock, fish, and crop production sectors (10 distinct crop-producing regions); the food processing industry, distribution, and retail markets; and a nutritional analysis of consumption.

The Division is also interested in the energy-integrated, or energy self-sufficient animal and crop production system concept, and is presently evaluating relevant technologies and experiments in order to devise a coordinated program of research, development and demonstration. The energy saving potential appears good, and the various research opportunities are promising. Demonstrations are needed to ascertain the sufficiency of animal and crop residues as fertilizer and fuel for energy-intensive operations such as irrigation, crop drying, and livestock housing on farms of varying sizes and capacities (crop/livestock/acreage relationships). Requirements for a package anaerobic digestion unit, methane storage, solar and

other technological installations, and "imported" fuels, as well as potential pollution problems and adoption of the system in less developed countries also need to be addressed.

In general, crop production research ideas submitted by the 1976 DOE workshop relate more specifically to the ongoing USDA research program to improve yield per unit of input through plant breeding, fertilization, and management than to the energy-oriented DOE objectives. For example, recommendations on reduced tillage (2), loss reduction in harvesting (4), multiple cropping (5), and genetic improvement (11) are being addressed by the USDA Agricultural Research Service and the State Agricultural Experiment Stations. Although projects of this type do have an energy parameter in that they impact on productivity, they are not included in the DOE Agriculture program because their conservation potential is peripheral compared to those projects with energy savings as a direct objective through improved processes and technologies. In view of the USDA activities and its extension network, it is doubtful that DOE's involvement could speed adoption of results beyond present efforts.

A comprehensive bibliography and listing of crop production research projects which, although generally not undertaken with conservation as a direct goal, impact on energy utilization indirectly, is contained in a USDA/FEA reference Energy in U.S. Agriculture: A Compendium of Energy Research Projects. It includes abstracts of research related to management and cultural practices, weed control, tillage and land preparation, irrigation, harvesting, insect and fungi control, frost protection, fertilizer, drying and storage, crop residue utilization, and livestock production. A series of first-step energy conservation tips for field crop producers, vegetable producers, and orchard managers is to be found in the new USDA Guides to Energy Savings.

The participants at DOE's workshop discussed research to reduce energy consumption in cold protection (6). The Division's Agriculture program is supporting a project at Pennsylvania State University to conserve oil in orchard heating. A model recently constructed by the Economic Research Service of USDA suggests that over 6 million barrels of oil are used in protecting fruit from frost damage during a typical year. Concern for energy conservation in frost protection has developed only recently. Consequently, there are many unexplored opportunities and unanswered questions about the energy efficiency of existing alternatives. The Penn State project will test the Orchard Foliage Temperature model, also known as the Welles model, to determine optimum heater placement and density, and size and shape of heaters to maximize the transport of heat to the trees. Methods of increasing the

heaters' radiant output, and whether "pulsing" heating systems require less fuel will be studied. The energy effect of disrupting (by insulation or reflection) heat transfer from heaters to storage in the soil will be investigated. Comparisons will also be made between the management of a heating system and an ongoing University demonstration involving sprinkling for frost protection.

One of the workshop recommendations dealt with cropping for more energy-efficient food chains such as the production of algae for protein (3). Again, research and development of new food sources and food chains would be more appropriately handled by USDA and the land grant universities. However, DOE is interested in exploring the utilization of waste heat from power plants, as mentioned in this recommendation, for aquaculture and algae production, and greenhouses. This topic is discussed in the Greenhouses and Other Intensive Production Systems section of this report.

Another of the workshop suggestions was for energy reduction through increased pesticide efficiency (13). Among all agricultural chemicals, energy conservation in the production of nitrogen fertilizers is the highest DOE priority because it is the most energy-consuming of all crop production operations, using six times the energy required in pesticide production. Over time, as DOE's fertilizer research and development program takes shape and conservation gains are effected in the fertilizer production industry, proposals regarding pesticides may be actively considered for funding. USDA and the Agricultural Experiment Stations are involved in testing and dissemination of optimal application practices, as is industry. Also, an EPA research program is underway on alternate pest management systems with the objective of refining strategies and tactics for insect pest control using crop ecosystems which permit marked reduction of dependence on pesticide chemicals.

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DAIRY AND ANIMAL PRODUCTION SYSTEMS

Currently, the Division of Industrial Energy Conservation has no specific projects underway in the dairy and animal production sectors. The work the Division is is presently undertaking relates to the processing of dairy and meat products. The Purdue Food Sciences Institute has just begun a comprehensive systems study for the Division in two dairy processing plants and two meat packing plants. This effort will quantify the amounts of water and energy usage and help point out areas for additional research to reduce energy consumption in food processing operations. The Division has undertaken two other projects relating to dairy foods processing: (1) a demonstration of high temperature heat pumps for milk drying with Garrett Airesearch and (2) a project with the University of Maryland to demonstrate the potential energy savings from producing and marketing acceptable aseptically packaged milk versus the current pasteurization systems. In meats processing the Division is funding two projects. Oklahoma State University is analyzing the potential for energy savings of hot deboning of beef and Georgia Tech Research Institute is conducting an energy balance and optimization analysis in the poultry industry.*

Dispite the fact that the Division has no specific projects underway in this area, it is still interested in identifying promising, non-solar technologies for research and development which are economically feasible and carry significant conservation potential and likelihood of adoption. The workshop project suggestion for an on-farm milk concentrator unit, for example, should be documented with an economic analysis, including net energy savings considering costs of transportation versus operation before it can be considered (54). The Division anticipates that research and development on the integrated energy farm system (detailed in the Fuel Substitution section) will include components related to the projects suggested at the workshop.

The recommendations for peak load experimentation on dairy and other livestock farms could be of interest in the future (34, 56). In agricultural production, the operations of water heating, irrigation and grain drying would be the likely targets for testing a variety of metering and minicomputer scheduling ideas to develop practicable methods of reducing peak loads.

Participants at the 1976 Agricultural Production workshop submitted several recommendations for enhancing the livestock production data base. Although DOE has no immediate plans, along these lines, energy use and efficiency information would probably be gathered as part of larger systems analyses or specific research projects. This would be especially true where gaps in the current state-of-knowledge inhibit conservation

*For a more detailed presentation see ERDA Programs and Objectives: Energy Conservation in Food Processing July 1977 CONS/2253-1 UC-95f. Available from NTIS.

developments (such as in recommendation 57, for example, on feed systems). The USDA Guides to Energy Savings for the Poultry Producer and For the Livestock Producer describe basic energy-saving equipment and practices in simple economic terms, as was suggested to DOE at the workshop (30). Economic analyses are always important components of DOE R&D efforts, since the success of the agency's programs depends ultimately upon market acceptance.

Other ideas, such as examining the potential for energy-flexible systems (31) or projecting future energy requirements for poultry and livestock production (25) could best be handled by the USDA Economic Research Service or the Engineering Extension network. The workshop also urged that additional information be assembled for farmers on environmental control (20) and conservation of energy in the use and construction of buildings for livestock production (19). Perhaps these ideas could be addressed in the many structural and equipment manuals disseminated by the three Agricultural Extension regional cooperatives - Farm Plans Service in the West, Midwest Plans Service headquartered at Iowa State University, and the Northeast Regional Agricultural Engineering Service at Cornell University. The recommendation on improvement of the energetic efficiency of animals by physiological and nutrional means is clearly more appropriate to USDA research objectives (15). The DOE Agriculture program does not plan to get involved in this type of pure biological or nutrional research, but will concentrate on technological innovations which can result in significant energy savings to agricultural producers.

DOE's Solar Energy Division is sponsoring a demonstration of solar thermal energy utilization in a milking parlor at the Beltsville USDA/ARS Genetics and Management Lab. The primary energy sink in dairying operations centers on the milking parlor and its associated activities. The objective of this project is to develop and refine a solar system, using commercially available apparatus and technologies, for demonstration of water heating, space heating, and relationships with cooling of milk in the milking phase of dairy production. An array of solar collectors (93 m^2 of flat plate collectors on the parlor roof) and an underground storage tank to contain the heated water for use during cloudy weather have been installed. A semi-automatic control system is used, and a heat exchanger and various space heater models are also being tested. Thermal energy is collected by pumping water through the collector surfaces, and is either stored or immediately utilized by fan coil units in the milking pit, or to preheat water going to the domestic hot water heater. Since installation of the solar heating system, operating costs of the electric water heaters have been significantly reduced (typically 35% depending on inlet temperatures). Early experience indicated that corrosion is a serious problem, so prevention techniques are being studied extensively.

A related DOE program is underway at the University of Arizona. Energy-related design criteria for dairy facilities in various climatic regions are being developed, as well as design criteria for solar collectors, storage, and heat exchangers and absorption refrigeration. The project is intended to extend the geographic and climatic scope of the use of solar energy in the milking phase of dairy production. In close cooperation with the Beltsville station, this effort will establish a demonstration in the Western desert area to assess the solar design differences required because of climate. These two experiments were discussed at the DOE Agricultural Production workshop as a possible foundation for a larger demonstration to incorporate recent advances in sanitation operations (27). DOE has no such plans at the present time, although the idea may be considered in the future.

A new USDA Guide to Energy Savings for the Dairy Farmer contains several energy-saving ideas and cost examples for water heating, ventilation and supplemental heat, milk cooling, vacuum pumps and electric motors used in dairy operations. USDA/ARS also has some smaller scale dairy energy modeling and environmental control studies underway.

Several DOE Solar projects are in progress to ascertain technique and equipment requirements for the application of solar energy to broiler production. At the University of Maryland, for example, fuel savings and physiological responses of chickens will be quantified. Several alternative solar systems are being compared in chicken brooding areas for DOE at Auburn University and the USDA Southeast Poultry Research Lab. Mississippi State University is using low-cost solar collectors, developed by modification of existing roof and wall surfaces on poultry houses, to determine relative efficiency in layer house environmental temperature control, and explore the feasibility of using solar heat to dry poultry manure in caged-layer systems. In a commercial poultry manure drying installation in California, the solar-powered drying system has been studied in comparison to a nearby natural gas-fired dryer to evaluate the viability of producing a feed ingredient or fertilizer product from poultry manure using solar drying.

Swine growing house solar heating is also being explored. One such project is investigating methods of extracting and storing solar energy in waste treatment impoundments to heat swine housing. Emphasis is on low-cost heat exchangers for use in corrosive media such as salt ponds, methods of covering ponds, and evaluation of heat pumps utilized in swine house heating and cooling. Another effort is a demonstration of an integrated solar energy collector and storage unit which

functions as a wall of the swine farrowing and brooding structure to heat ventilation air, at a swine research unit on at Kansas State University.

Each year, DOE sponsors a Symposium on the use of solar energy for poultry and livestock production together with USDA and several trade and professional societies. Descriptions and findings of major research projects, sponsored by DOE, USDA and others, are presented in detail.

GREENHOUSES AND OTHER INTENSIVE PRODUCTION SYSTEMS

DOE's Division of Solar Energy has an active program to study and demonstrate the applicability of solar energy to the heating and cooling of greenhouses. USDA is responsible for managing the agricultural aspects of the projects. The program includes studies of the optimum collection of solar energy and tests of various collector types and storage systems. Alternative designs of greenhouse structures and components will be tested, including: the type of collection, using either the greenhouse itself or in conjunction with external collectors and heat storage systems.

In connection with other solar projects, warm water heating of soil beds by buried pipe, foam insulations, reflective curtains drawn horizontally over the growing area and parallel to the walls, and techniques for sheet water flow through a plastic envelope of roof and walls will be studied. With DOE sponsorship, a demonstration is underway involving two greenhouse/residence combinations. Other efforts include a study of the feasibility and energy efficiency of a "bubble-covered" pond as an integrated solar collector and heat storage unit for greenhouses and homes, and growth studies in a greenhouse connected to an abandoned coal mine to evaluate the suitability of the environment when continuously ventilating the greenhouse with deep mine air. In addition, five full scale solar heating demonstrations are in progress in commercial greenhouses for ornamental plant production in Texas, Massachusetts, and Ohio, and intensive tomato growing operations in Pennsylvania and central California.

The workshop ideas on combining greenhousing with other agricultural operations such as aquaculture, drying or biomass production systems were read with interest by the Division of Industrial Conservation but there are no funding plans at this time (46, 51). The DOE Solar Division has a relevant project underway in Washington state, in which a 360 sq.ft. "parabolic" greenhouse uses a reflecting material to concentrate solar energy into a 5,000 gal. pond of water that acts both as a storage and as a growing area for fish (talapia).

The Cooperative Extension Northeast Regional Agricultural Engineering Service (NRAES) is sponsoring a workshop on greenhouse energy conservation this winter to share research experiences and technology transfer activities. This is a popular research topic at several universities, and there seem to be many areas where preliminary work has been accomplished but further development and demonstration is needed.

The DOE workshop submitted recommendations concerning the use of low grade waste heat in intensive agricultural production systems (38, 45, 48). The DOE Division of Conservation Research and Technology is interested in equipment and techniques to facilitate utilization of waste heat from power generating stations for greenhouses and other agricultural applications such as aquaculture and animal rearing facilities.

Several experiments with waste heat in greenhouses are underway around the country, some of which also involve soil warming research. TVA, in cooperation with DOE, is operating a greenhouse using waste heat from the Browns Ferry Nuclear Station. They have successfully conducted extensive engineering and horticultural work with cucumbers and tomatoes in a pilot conventional aluminum-framed glass-glazed structure using a direct contact evaporative pad design. Other major efforts include programs at Northern States Power, Yankee Vermont Nuclear Power Corp., and the Public Service Company of New Jersey. These projects will study engineering and horticultural questions and provide data concerning the economic potential of a commercial venture.

DOE's Division of Industrial Energy Conservation is sponsoring a study at Tufts University Nutritional Institute concerning the energy used in harvesting and processing of seafoods. The objective is to delineate and quantify the energy consumed in seafood harvesting, operation of aquaculture and mariculture systems, marketing, and preparation. Methods for reducing energy requirements will be pinpointed. Total energy input will be compared to the nutritional values of the respective foods. Seafoods to be included are canned sardines, pink salmon, yellowfin or bluefin tuna, fresh king salmon, cod, flounder, haddock, steamed blue crab, shrimp, lobster, frozen halibut, and scallops. Prepared seafoods such as frozen codfish cakes, frozen sole in lemon butter, and fish sticks will also be included. Energy inputs for aquaculture and mariculture production of catfish and oysters will be assessed so that their energy use efficiencies can be compared to conventional methods of seafood harvesting. This study will document in terms of energy costs and nutritional consequences, the effects of the various stages of food production and processing. Tracing individual food products through the food chain will provide data which can be used to make recommendations to both consumers and industries on changes which could save energy while maintaining good nutrition. The results of this systems study will be used in part to evaluate the feasibilities and energy-saving potentials of specific proposals for conservation research, such as those discussed at the workshop on aquacultural materials handling, vehicles, and other new technologies (47, 49, 50).

TRANSPORTATION AND MATERIALS HANDLING

Three groups at the workshop commented on the relative dearth of information about energy used in the distribution of agricultural products (1, 26, 44). When considering the food system holistically, transportation accounts for about one-fifth of the total energy use, but deficiencies in the data base concerning energy consumed in distribution of farm inputs, on-farm transportation and light duty operations, and hauling of animals and crops to processing facilities are common. Currently, most estimates are derived from fragmentary locational studies and aggregate national ton-mileage figures on the trucking and rail industries.

DOE is interested in the development of more complete, reliable statistics on energy involved in the flow of materials, and the factors such as packaging and storage that affect energy consumption in moving a product form one place to another. Such a study would have to be conducted on a large enough scale to accommodate wide variances in on-farm transportation modes and practices, and would probably best be undertaken on a crop-specific regional or state-by-state basis. The Division's Agriculture and Food Systems Branch has not yet addressed research needs in the transportation sector but is interested in establishing a program so that all aspects of energy conservation in the food system, from "the ground to the dinner plate" are included.

DOE's Division of Transportation Energy Conservation is charged with developing alternative transportation technologies, and has research underway on turbine and Stirling engines which can operate on a variety of fuels, longer-range electric and hybrid vehicles, and more efficient transmissions and other components for current engines. The focus is on technology and hardware rather than the distributional aspects of transportation.

Since many of the advances in automobile technology are expected to be applicable to trucks, DOE has limited its ancillary efforts to applications studies and the development of a waste heat subsystem to capture and recycle waste heat in diesel truck exhausts. Profile data on the refrigerated trucking industry has been compiled for inclusion in the Transportation Division's 1977 edition of the Transportation Energy Conservation Data Book. To date, the R&D ideas on new transport refrigeration technologies which have been reviewed have not met funding criteria because they have not evidenced significant market penetration potential due to cost and reliability factors. One project currently under negotiation in this area is development of portable instrumentation to

detect energy losses in refrigerated vans. This Division does not plan to single out the agricultural distribution sector for conservation research, and the likelihood of significant benefits accruing to farm operations from its vehicle R&D program is remote. The Department of Transportation has broad research and development responsibilities (coordinated with DOE's) which could, over the long term, impact upon the energy efficiency of the agricultural sector in small ways.

The USDA Agricultural Research Service has completed a variety of projects aimed at reducing physical, quality, nutritive, and spoilage losses of products, and the reduction of transport, packaging, refrigeration, and handling costs. One such effort is an examination of livestock losses in transportation, another is a feasibility study of containerized transport and storage systems for grain and soybeans. This latter concept was advanced at the workshop (69). The USDA study analyzed present grain storage and handling techniques, and identified regulatory and other impediments to containerization such as vehicular dimensions, costs, attitudes and financial positions of truckers and truck brokers, rail carriers, etc. The energy parameter was not specifically targeted. It was concluded that the potential for standard ISO containers in grain distribution is limited. The idea of loading grain directly into containers at the farm or country elevator for storage and shipping to processors or exporters was found to be uneconomic. Because grain is flowable and adaptable to bulk handling techniques, the current intermediate handling costs are small, and investment in higher priced containers specially designed for ease in loading and to withstand the stresses of shipping (and possibly fitted with drying equipment) would not be attractive to shippers or carriers. There is currently some movement of "special" grains (seed grains, extremely high quality grain varieties such as soybeans, which are often very soft and subject to much damage by crushing if shipped bulk), in certain types of containers, especially by the Japanese. This will likely continue.

USDA experimentation with food product distribution schemes has ranged from vehicle routing computer simulations to city market exchange docks and inner city buying/distributing organizations. USDA has explored, on a preliminary basis, alternatives to conventional transport refrigeration such as ventilated containers on ships, bio-regulators for fruit and vegetable crops, and a truck refrigerant system which derives energy from the truck's movement through air. The USDA Farmer Cooperative Service reports that the notion of transportation (for people) and distribution (for agricultural products) cooperative organizations is gaining adherents around the country as fuel prices increase.

Improvements in motor efficiency and load-matching were recommended by the workshop (21). FEA (which is now incorporated into the Department of Energy) has been working to identify areas of greatest conservation potential in electric motor use in the industrial and commercial sectors, and assessing the technological potential and economic trends that might influence the use of more efficient electric motors. A systematic comparison of actual operating efficiencies with listings in standard reference books published by the motor industry substantiated that the available guidelines bear little relation to actual operating efficiencies for a variety of reasons (maintenance, load-matching, etc.). FEA has submitted recommendations to the Congress which would establish official efficiency test procedures and promulgate labeling regulations. In the meantime, FEA has mounted an information dissemination program with a comprehensive new technical manual for motor end-users, Energy Efficiency and Electric Motors (available from NTIS) and a corresponding film. Dairy operators and irrigation farmers in particular may find this publication helpful in reducing their energy costs. Energy saving tips for electric motors are also outlined briefly in the USDA Guide for the Dairy Farmer, and guidance on maintenance and alternative motors is also available to agricultural users through the Agriculture Extension network and manufacturers. The National Electrical Manufacturers Association is in the process of developing more "realistic" guidelines for a voluntary efficiency testing and labeling program.

Feed handling uses more energy than any other livestock operation, or about 48 trillion BTU's. The workshop commented that improper load-matching is a major target for conservation (22), and also recommended that a systems study of feed harvesting and handling be undertaken to assimilate the vast amount of data available on alternatives from Agricultural Experiment Stations and USDA (29). The latter proposal would best be handled by USDA because it relates more to that agency's mission of optimizing production management and does not appear to carry a direct, significant conservation objective. More efficient use of electric motors in feed handling is being addressed by manufacturers of grain augers and other equipment and by the Agricultural Extension Service.