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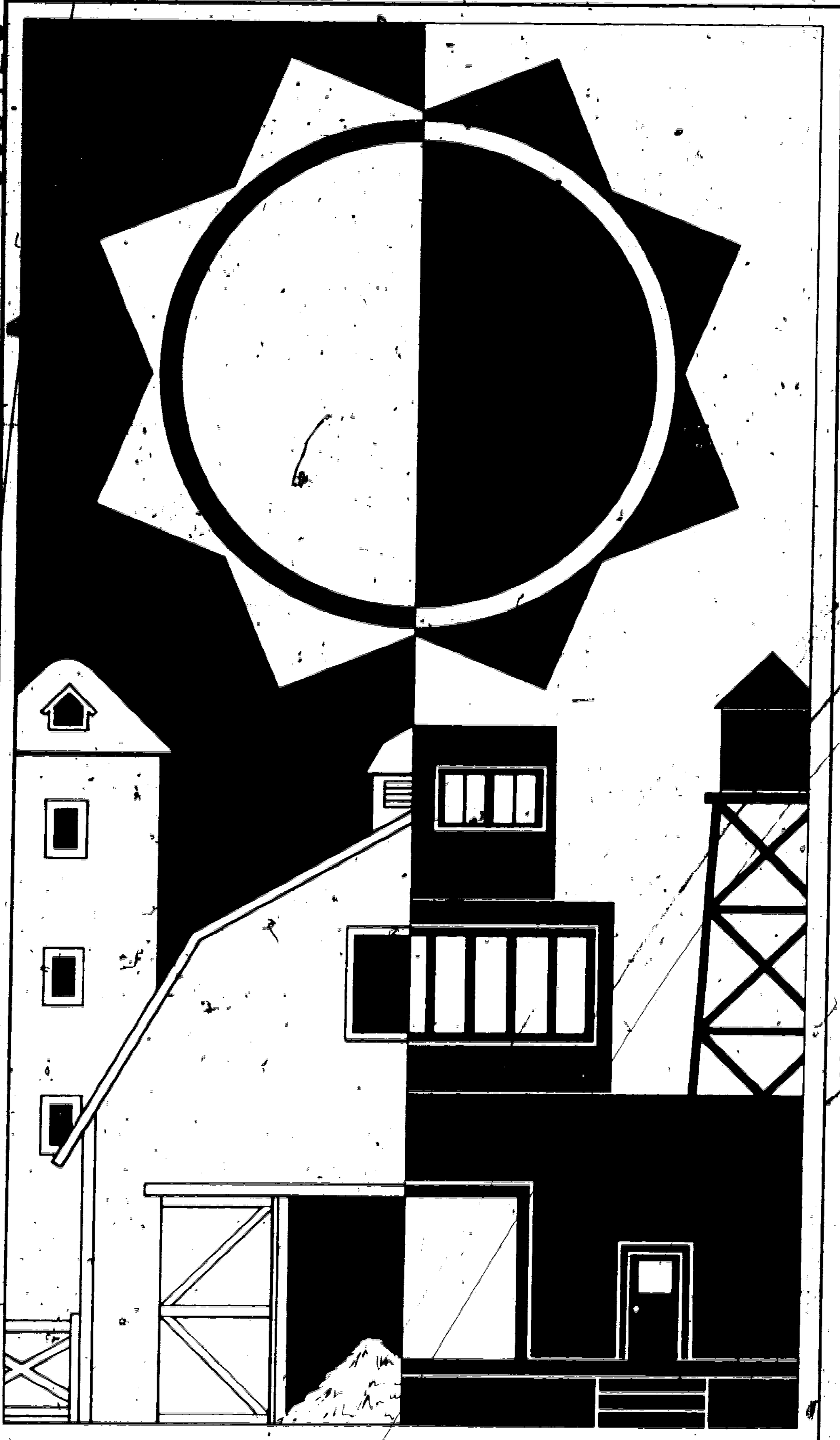
ABSTRACT

The purpose of this report is to present and prioritize the major environmental issues associated with the further development of solar energy as a source of process heat in the industrial and agricultural sectors. To provide a background for this environmental analysis, the basic concepts and technologies of solar process heating are reviewed. The potential effects of these applications of solar energy on the full range of environmental concerns are then discussed in terms of both their relative significance and possible solutions. The environmental impacts of the solar energy producing technologies are discussed. Finally, an environmental work plan is presented, listing research and development proposals and a National Environmental Policy Act (NEPA) document work plan which might help clarify and/or alleviate specific environmental and safety problems. (Author/MR)

ERDA 77-47/2

# SOLAR PROGRAM ASSESSMENT: Environmental Factors



## Solar Agricultural and Industrial Process Heat



Environmental & Resource Assessments Branch

Division of Solar Energy

Energy Research & Development Administration
Washington D.C. 20454

March 1977

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## SECTION I

## INTRODUCTION AND ENVIRONMENTAL SUMMARY

### A. Organization and Intention of Report

The purpose of this report is to present and prioritize the major environmental issues associated with the further development of solar energy as a source of process heat in the industrial and agricultural sectors. Agricultural and industrial heating represents the specific application of a variety of Federally-funded solar technologies. To provide a background for this environmental analysis, the basic concepts and technologies of solar process heating are reviewed. The potential effects of these applications of solar energy on the full range of environmental concerns (e.g., air and water quality, biosystems, safety, social/institutional structures), are then discussed in terms of both their relative significance and possible solutions. Although the development of solar energy as a source of process heat will contribute to some environmental problems common to construction projects and energy-producing technologies (e.g., construction noise, thermal discharge to the air and water), only those impacts unique to the solar portion of the technology will be discussed in depth. Finally, an environmental work plan is presented, listing research and development proposals and a National Environmental Policy Act (NEPA)* document work plan which might help clarify and/or alleviate specific environmental and safety problems.

### B. Salient Environmental and Safety Issues

Since many of the solar process heating concepts funded by the Energy Research and Development Administration (ERDA) are still largely in the developmental phase, the potential

* For a discussion of NEPA documents, see Section IV.

environmental issues presented here and in Section III of this report are based essentially on a review of technical subsystems studies and extrapolation of similar situations. The completion in the near future of the ERDA design experiments in this area, as well as projects using similar solar system components to provide heating and cooling and/or electricity, should provide the basis for a more detailed and precise assessment of the environmental impacts of agricultural and industrial process heating via solar energy use.

1. Land Requirements

The industrial and agricultural use of solar energy for process heating can be a land intensive proposition and as such raises questions of displacement of alternative land uses, the destruction or modification of natural habitats, and the desirability in terms of esthetics or community land use plans of committing a sizeable piece of land to solar energy collection. In small-scale applications of solar energy, collector systems can be located atop existing buildings or on rural property of marginal value. However, large-scale operations are likely to require as much as one hundred acres and may have a significant impact on land use. In agricultural applications this may mean the conversion of crop or grazing land or the clearing of land areas not yet in use and possibly of little other agricultural value. Due to the services available at central food and grain processing sites (e.g., transportation), land of some commercial value may be used. Industrial applications may involve the displacement of land in or adjacent to new industrial parks or plant sites. Large-scale solar-based process heating is unlikely to occur at sites which are already substantially developed and industrialized, because of the high cost of land acquisition at such sites.

In addition, deployment of large-scale process heat systems would potentially result in the clearing of natural vegetation and the possible paving of large tracts of undeveloped or agricultural land. Unique or significant habitats may be destroyed if various potential sites are not carefully evaluated before construction. In general, the compatibility of solar-based process heating with local and regional land use plans will have to be assessed, as well as the relative economics of foregoing commercial properties or agriculturally productive land use for the increased availability of solar-based energy. Zoning issues may present institutional barriers in this regard. The social costs and benefits of constraining use of lands will have to be weighed against the desirability of using a relatively non-polluting energy producing technology.

2. Glare and Misdirected Light

Misdirected reflected solar radiation from heliostats or collectors can be a significant safety hazard in certain applications of solar energy to process heating. For non-focusing collectors (flat plate, evacuated tubes, or solar ponds) the problem is relatively minor and easily controlled. Glare can distract vehicle drivers and/or be a nuisance to local residents or workers. These problems can be avoided through site selection and use and, where needed, the construction of barriers.

For focusing systems a misaligned collector or set of collectors concentrating and focusing solar radiation can produce a significant hazard. This misdirected radiation can potentially cause burns and serious glare problems with possible eye damage and glare problems; plant personnel may be required to wear protective goggles. This problem could be complicated by the proximity of the plant to local populations. Provisions for an "at rest" or "face down" position for the collectors may alleviate some potential dangers resulting from misdirected solar radiation. Finally, both terrestrial and overhead "exclusion areas" and protective barriers could prevent potential receptors from being subjected to the hazards of this phenomenon.

3. Product Contamination

Solar heating systems utilize a variety of chemical materials for energy storage and transfer including eutectic salts, petroleum oils, and working fluid additives (e.g., ethylene glycol, chromates) which can potentially damage products or contaminate food materials treated with solar-based heat. In addition, the physical and chemical conditions within the solar system will be conducive to the growth of bacteria and fungi which might damage the commodity being heated.

Contamination of products can have adverse economic impacts on the producer and consumer. In the case of food goods, the consumer may be exposed to health hazards. The possibility of commodity contamination can be reduced in a number of ways including the continuous monitoring of products and heat streams for contamination, the use of indirect heating methods which isolate the commodities from potential contaminants, and the selective use of storage and work fluids which prevent contamination.

4. Handling and Disposal of System Wastes

Various working, heat transfer, and storage fluids, such as hydrocarbon oils and salt solutions, will be used in certain process heating systems. The accidental or emergency release of these substances into the local environment could result in potentially serious pollution and safety hazards. From the safety standpoint, fire represents one of the greatest hazards.

Some of the substances contained in these fluids are highly flammable, especially when exposed to the atmosphere. Many of the liquid working fluids used in solar heating systems degrade or deteriorate with use: For this reason, these fluids have to be periodically flushed and replaced. The release of these materials into local water bodies could have potentially harmful effects on aquatic life.

Proper system control and maintenance should control fluid leakages. Selection of the least flammable and toxic working fluids can alleviate both potential fire and pollution problems. Finally, adequate chemical/fluid management can control possible impacts of both accidental and intentional fluid release. For certain materials it will be necessary to retain the more potent fluids in receptacles for subsequent disposal by other methods such as reprocessing or reclamation, chemical treatment, or incineration. Many of the potential industrial and agricultural solar energy users will have onsite equipment and/or experience in handling and treating chemical wastes.

SECTION II

# AGRICULTURAL AND INDUSTRIAL PROCESS HEATING

## A. Solar Energy Applications

### 1. Background

Forty percent of total national energy consumption is related to the industrial sector. As shown in Table II-1, 28 percent of this is attributed to manufacturing and the remaining 11.5 percent to agriculture, mining, and service industries. The primary energy source used by industry is natural gas followed by electricity and then oil. In 1972, coal provided only 15 percent of the total energy purchased by industry. The combined supply of oil and gas accounted for over half of the total demand.1/*

Of the energy purchased by industry, about 75 percent goes towards generating process steam or into direct process heating. In addition, a significant portion of the 25 percent attributed to electricity use could be functionally replaced by steam-powered turbine drive.2/

Historically, solar heating has been employed in U.S. industry. Primarily in passive applications, it has been used directly to dry food products and raw materials and to evaporate liquids. It also is applied in greenhouses to increase agricultural production.

The emphasis of the ongoing ERDA solar research program is to increase the role of solar energy in U.S. industry by developing solar energy systems which provide the quality of service needed for current industrial methods.

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* References are listed in the Reference Section at the end of the report.

## TABLE II-1
## DISTRIBUTION OF ENERGY CONSUMPTION BY SECTOR—1971

| | PURCHASED FUELS | | PURCHASED FUELS PLUS ELECTRICITY[a/] | |
|---|---|---|---|---|
| | $10^{12}$ Btu | PERCENTAGE | $10^{12}$ Btu | PERCENTAGE |
| ousehold/Commercial | 14,281 | 20.7 | 17,441 | 30.6 |
| ansportation | 16,971 | 24.6 | 16,989 | 29.8 |
| dustrial | 20,294 | 29.4 | 22,623 | 39.7 |
| Manufacturing | (14,329) | (20.8) | (16,085) | (27.9) |
| Non-Manufacturing | (5,965) | (8.6) | (6,538) | (11.7) |
| ectrical Generation | 17,443 | 25.3 | — | — |
| OTAL | 68,989 | 100.0 | 57,053 | 100.0 |

/ Purchased electricity valued at its thermal equivalence of 3412 Btu/kWh.

ource: Energy Conservation in the Manufacturing Sector—1954-1990, Energy and ıvironmental Analysis, Inc., prepared for the Council on Environmental Quality, ovember, 1974.[1/]

2. Industrial Energy Requirements

Industrial use of energy for direct or indirect process heat occurs in a diversity of applications. Required temperatures range from close to ambient for low-pressure distillations to above 3000°F (1647°C) for refractory kilns. The energy source selected for a given industrial use must satisfy both the specific temperature requirement and specific performance criteria. For some processes direct heating must be clean and free of pollutants (e.g., processes for heating textiles, bakery goods, and certain metals). Often precise temperature control (variability and accuracy) is required. For most heating processes dependability is an important factor, particularly in continuous processing. Another factor affecting the selection of an industrial energy source is the problem of treating residuals to meet environmental standards. This consideration imposes restrictions on the choice of fuels not only from the varying requirements of different industrial processes, but also from the variable environmental conditions for each geographical location. In short, the ideal industrial energy source is not only economical, but is also dependable, clean, and easy to control.

In light of these factors there are certain characteristics of solar energy which industrial users should find desirable. The primary attribute of solar energy is its cleanliness, both in conveying heat to the working material and the lack of residuals released to the environment. Solar energy should also be relatively easy to control if transformed to process steam or hot gaseous streams. The primary noneconomic drawback of solar energy use is the undependability of insolation. For many industrial heating applications, rapid response backup heating capability will be a necessary part of the solar system.

3. Solar Energy Applications

As a heat source to be used by industry, solar radiation is best suited to operations requiring low temperature heat applied in a dispersed and perhaps intermittent fashion in remote or rural locations.

Industry and agriculture utilize a significant amount of low temperature heat. InterTechnology Corporation, under contract with ERDA, has estimated that, including the preheating of materials going to higher temperatures, about 25 percent of all industrial process heat is supplied below 212°F (100°C) and 40 percent below 350°F (176°C). [3] Frequently, this low temperature heat is inefficiently provided by combustion of fuels capable of providing higher temperature heat.

Solar energy can be used to meet these energy needs through the generation of hot water, steam, and hot gases for use in the processing operation.

Solar energy will be of particular use in cases where intermittent supply is acceptable. At major facilities using continuous processing, a regular and dependable energy supply is a necessity, and storage and/or backup supply is needed with any solar system. However, when intermittency is acceptable, as in drying or the evaporation of liquids, the economics of solar technologies will be greatly improved.

Rural or remote industrial and agricultural operations are well-suited to solar energy use. For these operations, transmission costs associated with all other conventional energy sources are eliminated, and the land needed for collection is more likely to be available. As with other solar thermal (heat-producing) technologies locations with high levels of insolation such as the south and west are going to be most favorable.

Industries which appear to have significant potential for using solar thermal energy include mining (drying of various minerals), food (using large quantities of hot water), tobacco (drying and dehydrating tobacco with low-grade steam), textiles (hot air and hot water), furniture (warm air), production of certain chemicals (for example, synthetic rubber, soap, processing plastics, toilet goods, organic dyes, glauber's salt), petroleum refining (preheating crude oil prior to distillation), asphalt paving mixtures (hot air for drying), leather tanning, ready-mix concrete, curing concrete blocks, steel industry (pickling with warm acid solutions, phosphate treatment), motor vehicles (hot air for baking ovens), and fabricated metals (degreasing, baking, galvanizing). This list shows the wide range of potential applications of solar thermal energy in U.S. industry.[4]

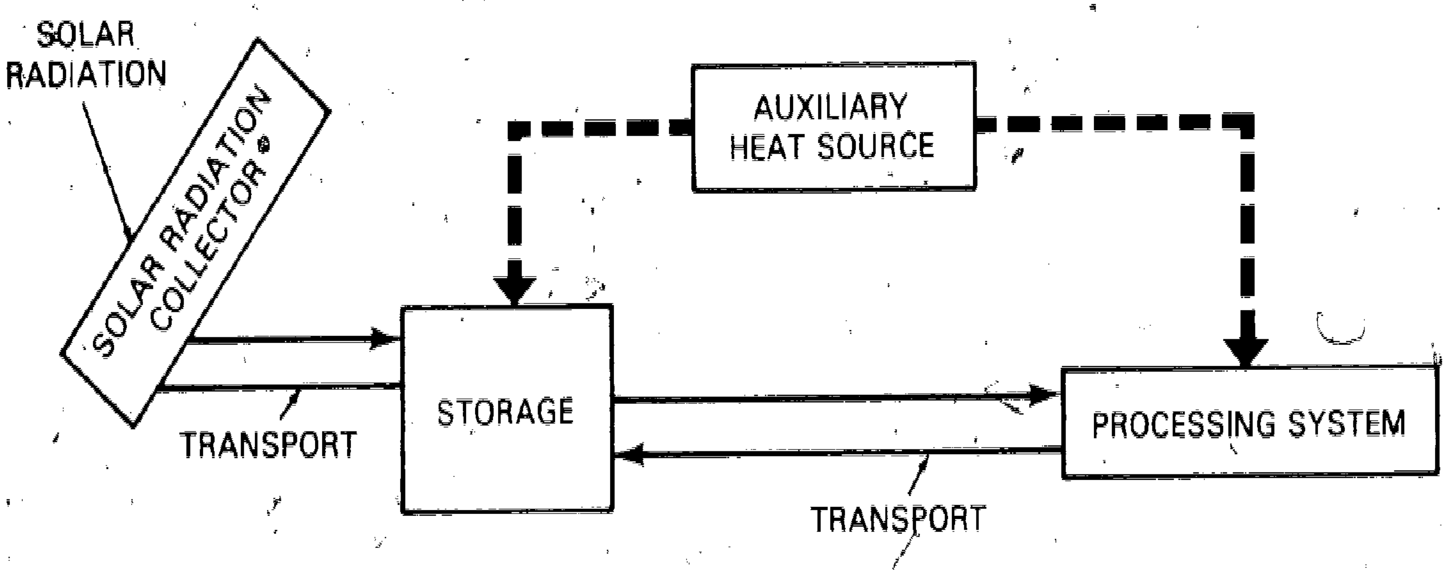
## B. System Components

### 1. Basic Concepts

The basic concepts behind industrial and agricultural solar systems are the conversion of solar energy into thermal energy and the application of this thermal energy either directly or indirectly to the heating of products or commodities. Typically, a solar collector is used to collect incident solar radiation and convert it to thermal energy which is then used to heat a working fluid. The heated fluid is transported to the point where it can be applied to process heating through direct contact or the use of heat exchangers. The heated working fluid can also be used to charge a thermal energy storage unit which can then be tapped during periods when no sunlight is available. Figure II-1 diagrams and explains conceptually the basic solar system.

Solar process heating systems vary greatly. Many components and subsystems are interchangeable and can be used for different applications. This section will give a des-

## FIGURE II-1
## SOLAR HEATING: PROCESS DIAGRAM




The system operates as follows. Solar radiation is absorbed by a collector and removed by a heat transfer (transport) medium to storage. Heat is removed from storage and distributed to the process by a heat transfer medium (may or may not be same medium flowing through the collector). Circulation throughout the system is by pumps, blowers, or other heat transfer medium moving devices. An auxiliary energy system is available both to supplement the output supplied by the solar system and to provide for the total energy demand should the solar system become inoperable. Manual or automatic controls maintain and monitor system operation.

cription of the alternative collection systems, heat transfer media and storage systems applicable to process heating.

2. Solar Collectors

A wide range of collectors can be used to capture solar radiation and convert it to thermal energy. The choice of collector is a function of the temperature desired and the cost of the components. The common collectors listed in order of temperature achieved (lowest to highest) are: (1) shallow ponds and translucent structures, (2) flat plate collectors, (3) tubular glass collectors, (4) focusing distributed collectors and, as a future option, (5) the central receiver system. Each is described briefly below.

a. Shallow Ponds and Translucent Structures

Shallow ponds and translucent structures are low cost systems capable of generating working fluid temperatures generally below 150°F (65°C).

A shallow solar pond is a special type of horizontal, flat collector in which costs are minimized by building large-area modules and using polymeric materials to replace the metal and glass used in conventional flat plate collectors. The "absorber plate" of a shallow pond is a layer of water, typically 2 to 4 inches (5 to 10 cm) deep and either flowing or static, contained in a plastic bag with a black bottom and clear top. The top glazing is a semi-rigid sheet of corrugated clear plastic arched over the water bag. A slab of heat insulating material under the water bag reduces heat losses into the ground and protects the bag from possible rodent and insect damage.

Transparent or translucent structures (greenhouses) take advantage of combining direct and indirect solar heating. The structure, made of glass, fiberglass, or plastic, captures solar energy and passively heats, warms, and/or dries the commodity inside. Heat which cannot be used immediately is transferred to a storage system normally through the circulation of the air in the room.

b. Flat Plate Collectors

Flat plate collectors are by far the most common type of collector in use today as they are used in space heating approaches. These units are currently being manufactured by companies ranging from small businesses to large corporations. The materials used and exact configurations vary greatly.

Generally, a flat plate collector consists of a metallic absorption plate (usually steel, copper, or aluminum) with integral or attached thermally bonded tubing. This plate is backed by an insulation material to prevent heat loss through the back of the collector. The absorption plate and insulation are usually placed in a metal container which is then covered with one or two sheets of translucent material, such as glass or plastic, and hermetically sealed.

The collectors are mounted on the ground or on southward facing rooftops (in the Northern Hemisphere) and tilted at an angle usually within 10 degrees of the latitude at which they are located. Incident solar radiation, both direct and diffuse, enters the collector through the transparent cover sheets and strikes the absorption plate. The latter is usually treated with either a black paint or a type of selective surface in order to increase its absorption of shortwave solar radiation. In addition, selective surfaces will significantly reduce the absorption plate's emittance of longwave thermal radiation, thus enabling the plate to retain more heat and reach higher temperatures.

The collector cover sheets, or glazing, serve two purposes. First, they create a dead air space between the absorption plate, thus significantly reducing losses through convection. Secondly, the transparent cover allows shorter wavelength sunlight to pass through and strike the absorption surface, yet at the same time it blocks longwave radiation emitted by the absorber from passing back through the cover to the external environment. The maximum temperature achievable witn a flat plate collector is around 200°F (93°C).

c. Tubular Glass Collectors

Glass solar collectors are usually of tubular configuration and employ an evacuated insulation chamber to reduce heat losses due to convection and conduction. They are generally able to achieve higher efficiencies than flat plate collectors and are especially useful for higher temperature [>200°F (93°C)] applications. The tubular configuration employs the same basic production technology used in tubular fluorescent light bulbs, and a number of firms are presently developing these units.

A typical glass collector consists of two coaxial tubes between which is formed a permanent vacuum to reduce conduction and convection heat losses. A selective coating is applied to the outer surface of the inner tube in order to reduce radiation losses. The working fluid enters and leaves the inner tube through the same end, using a reverse flow path aided by a feeder tube which is coaxial to the other two tubes. The fluid may be routed through a series of these tubes via a manifold device, thus forming a complete collector array.

These units can use either liquid or air as a working fluid and can operate at temperatures of up to 300°F (149°C). Tube spacing and orientation, as well as level of evacuation, tube and wall thickness, and materials, are important performance determinants. In addition, a diffuse reflecting surface used as a backplate can be added to increase the solar radiation intercepted by the absorber tubing.[5/]

In addition, the tubular glass collector, because of its basic configuration, tends to maintain a more stable efficiency throughout the day than a standard flat plate design. This is because the tubular configuration can intercept almost as much incoming solar radiation in the morning and afternoon hours as it can during the mid-day period.

Tubular glass collectors are also attractive because they can use the already existing technology associated with fluorescent lighting. Thus, economies of mass production may be realized quite early, making tubular glass collectors competitive in the solar collector market.

d. Focusing Collectors

Focusing or concentrating solar collectors focus solar radiation on a focal point or focal axis which represents a comparatively small area relative to the reflecting surface. This concentration of radiation on a small area enables significantly higher temperatures to be generated than with a non-focusing system.

Focusing collectors are best suited to areas with mostly clear skies and minimal air pollution, because focusing units can only make use of direct, not diffuse, solar radiation (a flat plate unit can absorb both).

Focusing units typically employ one of two basic configurations: the cylindrical parabolic trough and the circular dish. The cylindrical unit employs a parabolic-shaped reflecting surface (usually a polished metal such as aluminum) which focuses direct solar radiation onto a linear absorber pipe (located in the focus of the parabola) containing the liquid working fluid. The absorber pipes may be interconnected to form a linear array of trough collectors.

The circular collector focuses direct radiation on an absorber which is located at the focal point of the parabolic dish. The absorbers of a series of dish collectors may be interconnected with insulated piping through which the working fluid is pumped.

An offshoot of the linear focusing configuration is the segmented mirror concept. This involves replacing the unitary parabolic trough reflective surface with a series of smaller, more easily movable mirrors (which may be concave or flat). The angles of these mirrors are adjusted in a coordinated manner to focus solar radiation on a stationary absorber pipe.

There are other concentrating collector configurations, some of which need not track the sun. One example is worth mentioning because it is a concentrator which employs a basic flat plate design, making it easily adaptable to rooftop systems. The Compound Parabolic Concentrator (CPC) developed by Argonne Laboratories "is a non-tracking solar collector consisting of two sections of a parabola located symmetrically about the collector midplane."6/

Incident solar radiation reflects off the parabola walls and is concentrated on the portion of the flat absorber plate located in the center of the trough. A series of these troughs are arranged in a parallel manner in a glazed panel which resembles a flat plate collector.

A number of focusing collector designs have incorporated Fresnel lenses to focus incoming solar radiation. The basic design of a Fresnel lens is a sheet of transparent plastic (or other appropriate material) with a series of circular grooves cut into it. The grooves serve to refract the light passing through at a slight angle, focusing it on a given target. A Fresnel lens focusing collector must be adjusted periodically, however, to account for latitudinal effects.

e. Central Receiver

The central receiver system focuses a large amount of incoming radiation on a single elevated receiver. This system represents a long-term future option for industrial process applications and would be used to generate very high temperature [upwards of 1000°F (537°C)] heat. An in-depth discussion of the central receiver system can be found in other reports prepared by Energy and Environmental Analysis entitled Solar Thermal Electric and Solar Total Energy Systems.[7/8/]

3. Heat Transfer Components

A variety of gaseous and liquid materials are used to transfer thermal energy from the collector to storage, the collector to the processing unit, and from the storage system to the processing unit. Choice of the heat transfer medium depends on the type of collector, the temperature, the mode of heat transfer (direct or indirect), and cost.

Low temperature systems typically utilize air or a water-based solution for heat transport and transfer. The heated fluid is pumped to the distribution subsystem and/or the storage subsystem, where it is used immediately or stored for later use. Liquid systems require tubing and pumping power. Air systems, on the other hand, require larger ductwork and blowers, but in most cases they may be used directly for heating without a heat exchange process. Air also has the benefit of not being subject to freezing.

Liquid systems must be protected against freezing. During extended cloudy periods with below freezing temperatures, liquid working fluids may freeze, thus causing extensive damage to the solar system. To guard against this, liquid fluids may either be drained from the collector into the insulated storage tank, or, more commonly, they may be treated with anti-freeze solutions such as ethylene glycol.

In addition, liquid working fluids may corrode metallic absorption plates and tubing, as well as be subject to bio-fouling. Consequently, most liquid fluids are treated with corrosion inhibitors such as sodium nitrate and various chromates, and biocides such as chlorine. Additives to control the pH level, such as sulfuric acid, may also be included.

The working fluids currently under consideration for use in high temperature systems include high molecular weight oils such as Monsanto's Therminol 66, HITEC (a eutectic combination of potassium nitrate, sodium nitrite, and sodium nitrate), high-pressure water, and high temperature steam.

4. Storage System

The function of the thermal storage subsystem is to store thermal energy generated by the collector/concentrator system in excess of that required for normal plant operation and to supply this stored energy at times when direct solar radiation is not available (i.e., because of cloud cover or darkness).

At present, thermal storage technology employs the sensible heat transfer and/or latent heat of fusion properties of various storage "media." The latter method involves a phase-change and makes use of the relatively narrow freeze-thaw temperature ranges of selected materials, such as eutectic salts [for example, molten sodium hydroxide (NaOH) and potassium hydroxide (KOH)]. Sensible heat storage does not involve a phase change but makes use of the high specific heat properties of such materials as rock, hydrocarbon oils, and water.

These storage media are held in storage tanks. In the charge mode, solar heated working fluid generated by the collection system and in excess of the amount needed is diverted to the storage system and enters the storage tank. The working fluid then transfers heat to the oil, rock, or water and/or causes eutectic salt solutions to melt, thereby extracting and holding heat. When stored heat is required, the process is reversed with the oil or rock transferring heat back to the working fluid and the salts freezing, thus releasing heat to the feedwater to produce the requisite operating temperatures.

Process heating solar systems can use a range of storage media, depending on the temperature desired and transfer medium used.

## C. Specific Applications

### 1. Industrial

Industrial manufacturing applications of solar energy are quite varied. For integrated manufacturing facilities no two locations have identical energy demands and associated economic considerations. Table II-2 shows a list of factors influencing the exact choice of an energy supply system of which the solar heating system is likely to be just one element. Below is a description of exemplary applications of solar energy to industrial manufacturing.

## TABLE II-2
## FACTORS INFLUENCING ENERGY SYSTEM CHOICE

1. Ability to meet design and operating specifications.
2. Capital cost.
3. Operating costs.
4. Fuel costs and availability.
5. Dependability.
6. Simplicity of operation.
7. Availability of equipment.
8. General industry experience with equipment in the particular application.
9. Purchaser's experience with equipment.
10. Adequacy and accuracy of performance data.
11. Experience with vendor.
12. Limiting vendors to reduce spare part inventory.
13. Potential secondary benefits—noise level, improved product qualities, environmental impact, safety.
14. Degree of company energy consciousness.

a. Hot Water Projects

As a part of the ERDA program for industrial solar heating, the agency funded five research and design projects in hot water generation which are representative of the variety of potential solar applications. The five hot water users are:

- Can Washing -- In this project a solar system is being designed by Acurex Corporation to supply heated water to be used to wash empty and full soup cans on one of 20 parallel can washing lines at a Campbell Soup plant in Sacramento, California. The collector field is made up of a mixture of flat plate and trough shaped parabolic concentrating collectors producing water at 190°F (88°C);

- Curing of Concrete -- In this project hot water from a solar system will be used to cure concrete blocks. The collector system consists of a fixed collector bar mounted over a bank of movable blade reflectors which focus radiation on the collector bar. It is designed to give a 24 to 1 concentration effect, operate at 50 percent efficiency, and produce water at over 140°F (60°C);

- Textile Processing -- In this project a mixture of water and ethylene glycol will be heated to 250°F (121°C) using a high performance collector. The working fluid heat will be transferred to a secondary water stream supplying a dye tank;

- Laundry -- In this project both hot water and steam are to be generated with a solar system for use in linen cleaning. The collectors use mirror concentrators with individual tracking drive aimed at a stationary receiver tube. The hot water component is proposed to generate 200°F (93°C) water with over 60 percent efficiency; and

- Uranium Mill -- In a demonstration project now under way in New Mexico, a shallow solar pond built in the ground has been covered and used for hot water generation. Water heated to 114°F (46°C) is produced and pumped to a nearby uranium mill.

b. Hot Air Projects

The ERDA has recently funded six design projects in the use of solar-based hot air to meet industrial processing needs primarily in the drying and/or dehydration of a range of commodities. The projects include:

- Lumber Drying -- In this project solar-generated hot air will be used to dry hardwood lumber in a conventional lumber kiln. A flat plate collector will be used to produce drying air at 110°F to 180°F (48°C to 82°C);

- Food Drying -- In this project a set of flat plate collectors will be tested in various modes (direct use, storage to drier, and with an auxiliary booster) to dry a variety of food goods;

- Soybean Drying -- A conventional grain dryer in Decatur, Alabama, will be used to dry soybeans using drying air principally from a solar collector and storage system. A 14,800 square foot (1,375 square meter) collector mounted at an angle next to the concrete drying silo can dry up to 3,600 bushels (127 cubic meters) per day;

- Onion Dehydration -- This project will demonstrate the use of solar hot air on a continuous conveyor dehydrator which processes over 6,000 pounds (2,724 kg) per hour of onions using variable temperatures in a 4-stage drying sequence;

- Textiles -- A solar concentrating half-axis parabolic collector will be used to produce steam which will heat a cylindrical dryer. This will then support the open air drying of textiles at an Alabama plant; and

- Dehydration of Alfalfa -- Solar-based hot air will be used to preheat combustion air for a gas-fired rotary dehydrator that produces 3 tons (2,724 kg) of dried alfalfa per hour.

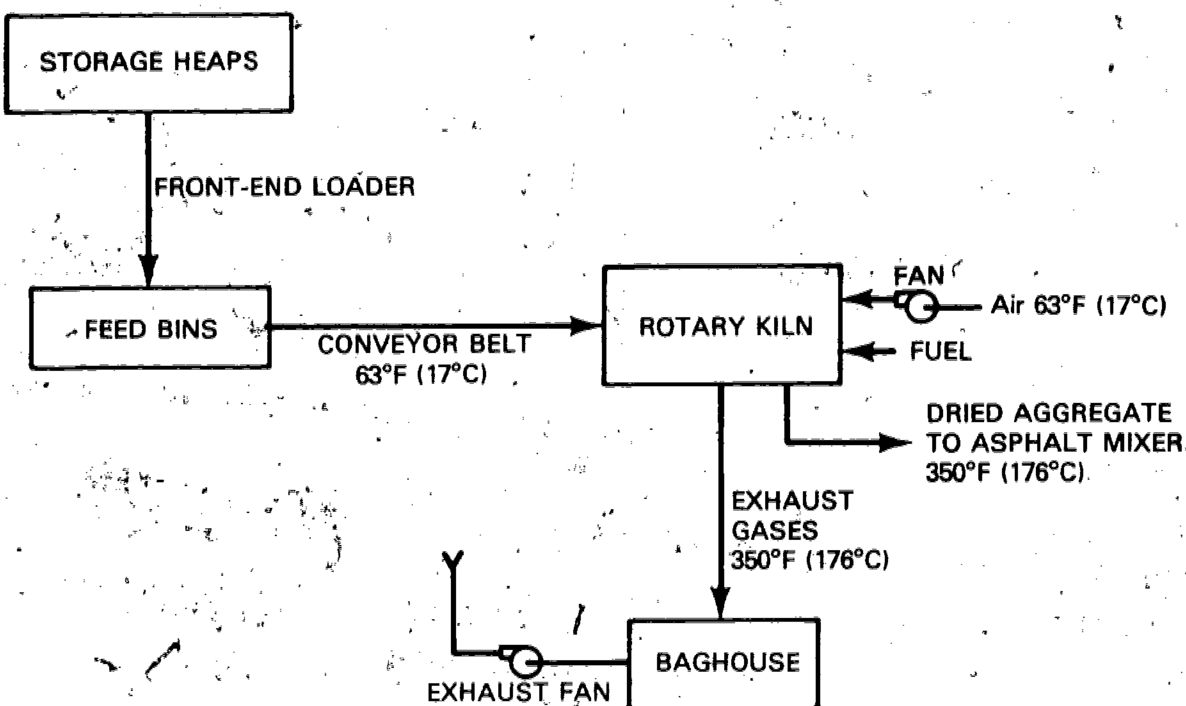
c. Steam Projects

The ERDA is in the process of developing a third set of experiments aimed at the use of solar-produced steam. It is anticipated that the low-pressure steam generation will find its greatest application at facilities which require exclusively low value heat sources. Food processing is a particularly promising area as cooked foods and dried foods or grocery products are well-matched to solar energy system capabilities.

d. A Case Example of Integrated Solar Heating and Conservation -- Aggregate Drying in the Asphalt-Mixing Process

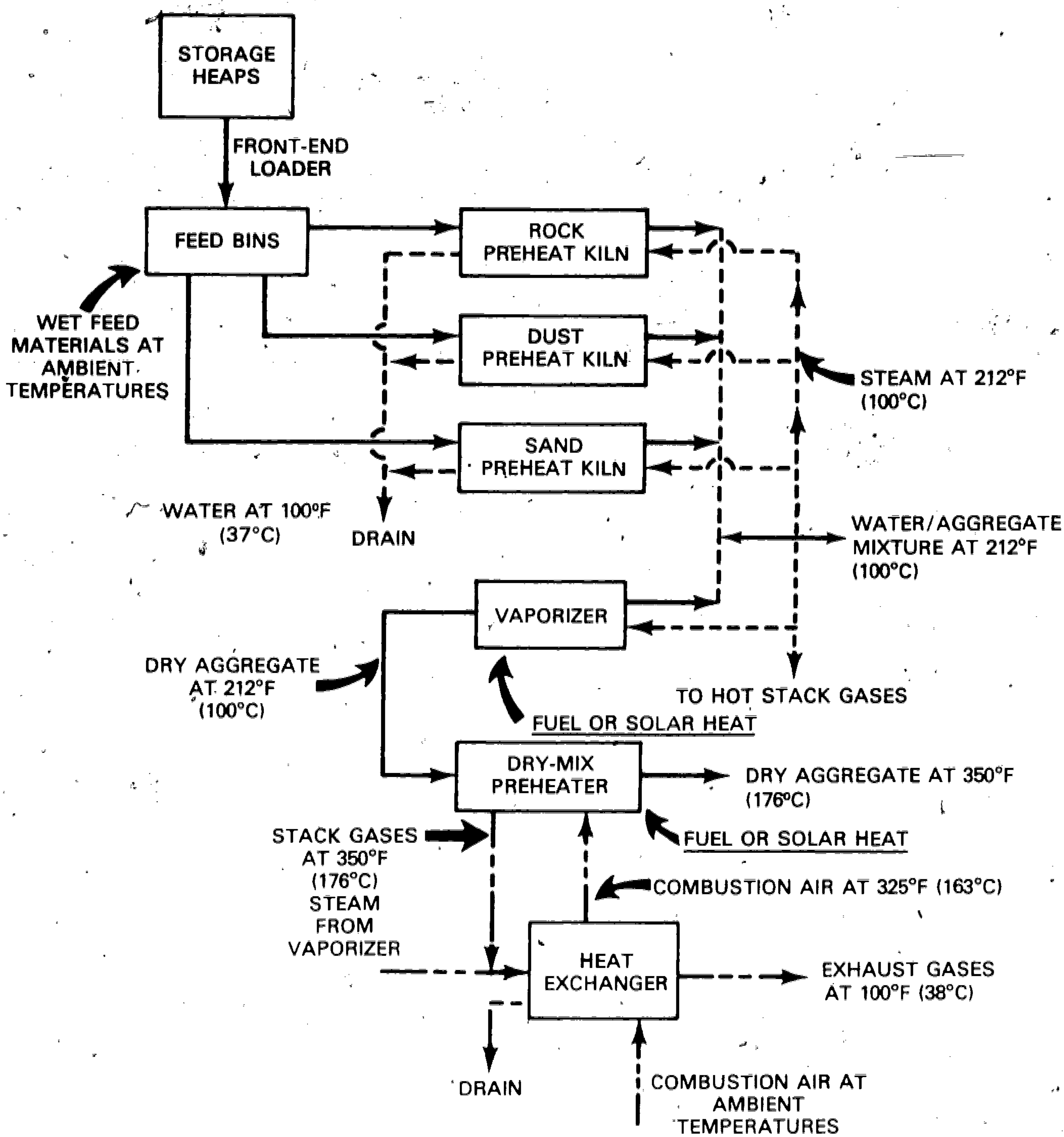
With careful design solar heating can become an integral part of a process rather than an add-on heat source. This example will identify specific points in a somewhat typical industrial process (that of aggregate drying) where solar energy can be applied beneficially and thus result in energy savings.[9/] In the existing mixing-aggregate drying process (Figure II-2) the major energy consumer is the rotary kiln, in which water is removed from the wet aggregate. This process (for a 7-ton mixer) requires a total heat input of 120 million Btu/hr at a peak production rate of 500 tons (453 metric tons) per hour. The process generally makes use of low temperature heat and therefore is compatible with solar energy systems. In addition, certain energy conservation measures, such as using flue-gas (normally waste heat) to heat the dust, can be applied to the process. Figure II-3 illustrates the drying process with the

**FIGURE II-2**
**PRESENT CONFIGURATION OF ASPHALT PLANT**




Source: Intertechnology Corp., Survey of Applications of Solar Thermal Energy to Industrial Process Heat.[9]

**FIGURE II-3**
**ENERGY-CONSERVING DESIGN WITH SOLAR HEAT**




Source: Intertechnology Corp., Survey of Applications of Solar Thermal Energy to Industrial Process Heat.[9/]

incorporation of energy conservation measures and flat plate solar collectors operating at approximately 212°F (100°C) to vaporize water. The drying process has been isolated so drying occurs at 212°F (100°C). The dried aggregate is then preheated to the 350°F (176°C) required for the asphalt mixing process. Water vapor from the drier is condensed on the incoming wet aggregate. The condensate is drained from the already saturated aggregate, thereby preheating the aggregate; some is sent to the heat exchanger for preheating the incoming combustion air. Inter-Technology Corporation estimates that the combination of solar energy use and energy conservation measures can result in a heat input savings of 58 million Btu/hr in this particular aggregate drying process.[9/]

## 2. Agricultural Applications

Applications of solar energy to agricultural activities include the heating of greenhouses and animal shelters and the drying and curing of grain, forage, and various crops.

In many of the solar applications in agriculture, direct use of solar energy already plays an important role. Nevertheless, a significant amount of fossil fuel presently goes into the low temperature heating and drying operations just because of the convenience, historical economics, and dependability of fuel-fired operations. Work in the agricultural area is therefore focused on optimizing the effectiveness of passive solar heating applications and the increased use of solar heat through more elaborate collection/storage/control solar systems.

The use of solar energy in the agricultural sector is particularly desirable as the drying and heating requirements best suited to solar use are now being met with liquid petroleum (LP) gas and to some extent natural gas which are both at a premium. LP gas is used on farms for a number of purposes, including fuel for motors, for drying crops, and for brooding poultry and livestock. In 1971, 46 percent was used for non-motor purposes.[10/] Decreasing demand for LP gas for motor use has been offset by increasing use for non-motor purposes, such as crop drying, tobacco curing, and space heating of broiler houses and young livestock housing. The same areas are now being explored for increased solar energy use.

a. Greenhouses

A conventional greenhouse, by its nature, is a direct application of solar energy. However, the effectiveness of a greenhouse can be increased by redesign and the use of specific absorption surfaces, thermal storage, and flat plate collectors. Redesign of the greenhouse in these ways can reduce the need for nighttime fuel-fired heating. The greenhouse can also be coupled with a residence allowing integration of the energy system for both facilities and providing cost reduction opportunities. In addition to heating, solar-based absorption cooling is being evaluated by several ERDA-funded investigators for its applicability to greenhouses or combined greenhouse/rural residences. The components of greenhouse solar systems include a variety of devices (insulators, absorbing surfaces, heat storage, and flat plate collectors, and, for cooling, a variety of small-scale concentrating devices).

b. Animal Shelters

Housing and cooling of animal shelters is generally analogous to home heating and cooling applications with, in some cases, greater tolerance for high or low temperature excursions. Systems currently being designed or demonstrated include shelters for dairy cows, chickens, and swine. Most designs incorporate flat plate collection, storage, and integrated use of solar energy in waste treatment. Poultry shelter applications by W. H. Brown of Mississippi State University and B. Horsfield of the University of California incorporate manure drying (for use as feed or fertilizer) with space heating. 11/

c. Drying and Curing

The third major application of solar energy in agriculture is in the drying and curing of grains and crops. Work is now underway to improve the application of solar energy to crop drying and curing. Fossil fuel use in this area, particularly corn drying, has increased rapidly because farmers have switched from harvesting corn on the cob to the more economical field-shelling method and are harvesting earlier to reduce the uncertainty of losses from field dried grain. Also, shelled corn is more easily handled than ear corn and the greatly reduced volume harvested saves labor and fuel.

The conversion to field-shelling technology -- combines and picker-shellers -- has been rapid. From 1960 to 1972 field shelling in the Corn Belt increased from 15 to 77 percent of corn acreage. The shift has occurred in other areas, too -- 62 percent of U.S. corn acreage was harvested as shelled grain in 1969. 10/

Artificial drying has increased accordingly. About half of the corn was dried on the farm in 1973 and nearly all of this required LP gas. About 20 percent of the corn was dried off the farm; about half of this required LP gas and the remainder required mostly natural gas. 10/

The solar techniques now under development are keyed to drying corn and grain crops after harvesting.

In addition to the large use of gas for drying corn, moderate amounts of LP gas are used in drying wheat, soybeans, rice, grain sorghum, and other small grains, and for drying peanuts during a two or three-week harvest period. LP gas is used extensively in curing tobacco. In 1973, tobacco used approximately 390 gallons (1,478 liters) of refined petroleum fuel per acre of crop, much of which went into the curing of the tobacco.[11/]

Recently a team of researchers at North Carolina State University demonstrated a solar energy system for bulk curing which reduced the fuel demand by 37 percent compared to a conventional bulk curing barn. The system includes heat absorption panels, air circulation and heat storage in gravel. Solar heat is used directly in the barn and for preheating furnace air. Figure II-4 shows the basic system layout.[11/]

d. Integrated Agricultural Systems

Since solar heating systems can perform a variety of functions around a farm, it is expected that commercial use of solar heating systems will involve integration of several uses such as space heating for the house and the livestock areas, water heating, grain and forage drying, and greenhouse heating. In this way the total demand for natural gas and liquid petroleum gas in rural areas can be greatly reduced, and the system's cost spread over several functions.

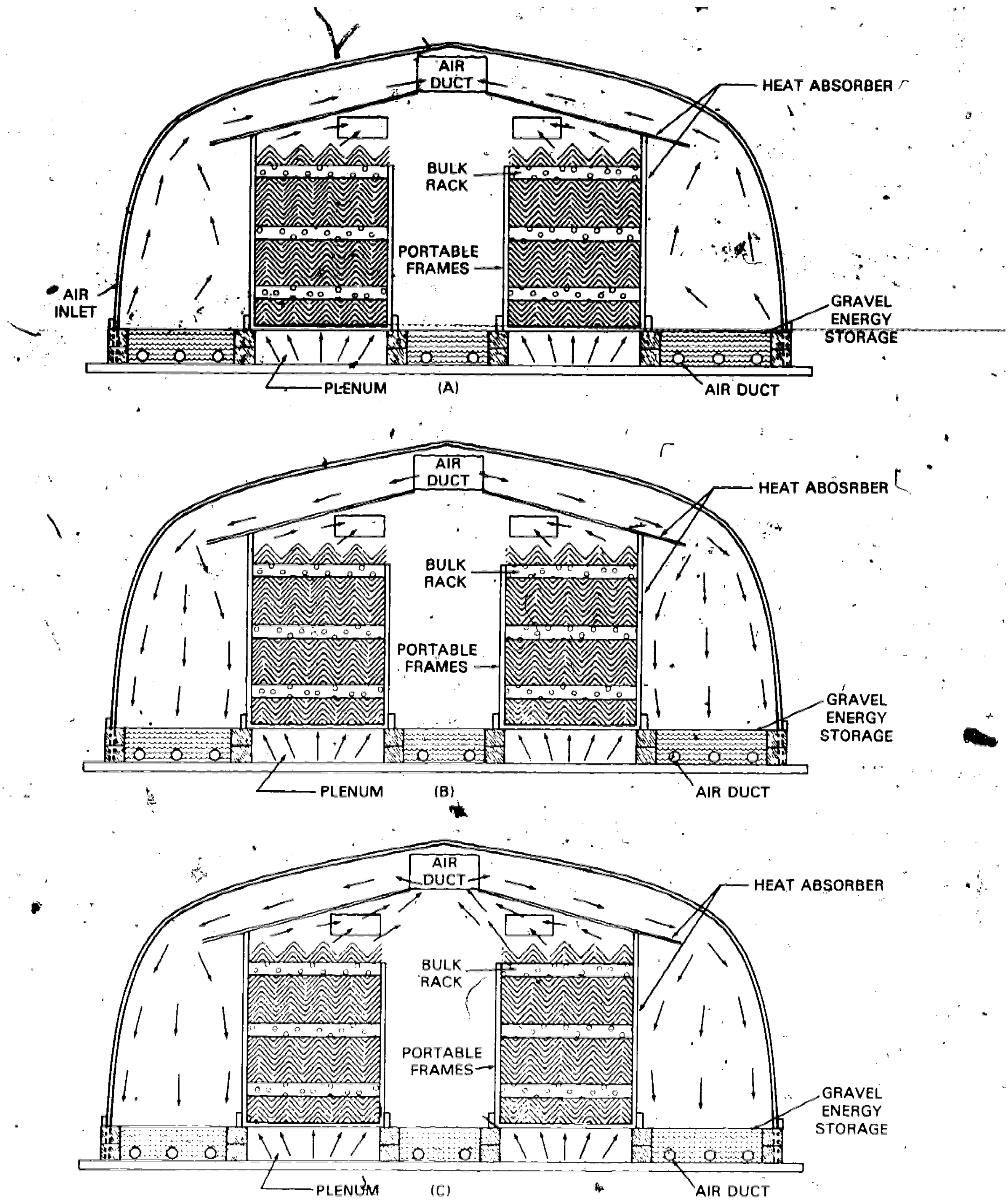



Figure 1—

Cross-sectional view of bulk curing/greenhouse system: (a) Solar energy used immediately during daytime to cure tobacco, (b) Solar energy stored in gravel during daytime for night use, (c) Total structure used as a heat exchanger for dehydration during nighttime yellowing.

Source: Summary of FY 1975 Research Programs for Use of Solar Energy in Livestock Shelters, ERDA Working Document, 1976.[11]

## SECTION III

## ENVIRONMENTAL AND SAFETY IMPACTS

### A. Introduction

Solar process heating systems incorporate a number of solar technologies, and thus the associated environmental and safety impacts will be of a diverse nature. Essentially, the impacts encountered will stem from the two basic functions of solar concentrating and flat plate systems. This section will examine these impacts, concentrating on the solar portion of the technologies. Conventional impacts, such as those stemming from auxiliary fossil fuel-fired boiler operations, will be only briefly addressed.

### B. Air Quality

Air quality impacts are expected to be minimal, at least insofar as the solar portion of the technology is concerned. Air quality effects which do result will stem from the conventional and auxiliary equipment associated primarily with back-up operation (i.e., conventional fossil fuel-fired auxiliary boilers or heaters).

Onsite fossil fuel-fired backup units, if used, will produce the usual combustion-related emissions such as particulates, $SO_x$, $NO_x$, CO, and hydrocarbons. The impacts of these emissions will vary with the size and extent of use of the backup units themselves, the type of fuel burned (oil or natural gas will probably be the most common auxiliary fuels because of the relatively high costs associated with coal burning on such a small intermittent scale), and the meteorological conditions at the site. These impacts, however, are not peculiar to the solar system, but are common to fossil fuel-fired operations.

## C. Water Quality

### 1. Working Fluid Release

#### a. High Temperature Fluids

Individual process heating systems may make use of various heat transfer fluids in association with high temperature operations and thermal storage. Fluids which are currently being considered for these applications and which are of concern environmentally include hydrocrabon oils and various eutectic or near-eutectic salt combinations. These fluids could be released to the environment and affect local water quality as a result of intentional system flushing operations or accidental leakage. (Periodic system flushing would be required in order to replace degraded fluids or to carry out maintenance.)

The release of these oils or salts could impact the environment in a number of ways. In terms of water quality, their release could contaminate local water supplies, particularly in rural areas where groundwater, untreated, is used for drinking supply. Ingestion of contaminated water would produce serious toxic effects.

Of particular concern are the inorganic nitrates and nitrites (the sodium and potassium salts). Small, repeated ingested doses of nitrates deposited in drinking water supplies may lead to weakness, general depression, headache, and mental impairment. In the digestive tract of humans and animals, the nitrates are reduced to nitrites by some of the common intestinal bacteria, particularly the coli bacillus.[12/]

Ingested nitrites can cause a cell respiratory condition known as cyanosis. Nitrate-nitrogen levels in water above 8-9 ppm can precipitate this illness. The Public Health Service recommends restriction of the daily intake of nitrites in man to 0.4 mg/kg body weight. Nitrites can also induce circulating blood stagnation which results in increased organism oxygen hunger.[12/]

Perhaps the most serious effect of nitrite ingestion is the formation of extremely potent carcinogens known as nitrosamines (formed via the reaction of nitrites and amines either in water or in the body). A recent Chinese study has linked the very high esophagus cancer rate in Hunan province with environmental nitrites, nitrates, and nitrosamines.[12/]

The EPA has established the maximum acceptable concentration of nitrate-nitrogen in raw water used for drinking water supplies at 10 mg/l while the maximum acceptable concentration of nitrite-nitrogen in raw water used for drinking water supplies is 1.0 mg/l. (This level may not be acceptable because of nitrosamine formation implications.)

The release of heavy oils could also significantly impact water quality. The EPA has stated that oil should be "essentially absent from raw water used for drinking water supplies" since, in any amount, oil will result in taste, odor, and appearance changes and may be a possible human health hazard.

Proper chemical management of system flushing operations should prevent serious impacting of local water quality. Certain of the spent fluids, such as the oils, may be suitable for reclamation processing. It is estimated that from 60-75 percent of degraded oils may be reclaimed using presently available techniques. These reclamation processes, however, may result in secondary environmental impacts.

Presently available industrial chemical disposal methods should prove adequate to handle flushed fluids which are not reclaimable. This problem is further mitigated by the fact that flushing operations are expected to occur infrequently.

Fluid leakage and/or spillage would be an accidental occurrence and is not expected as a result of normal process heating system operation. Proper and periodic system maintenance should be adequate to prevent major fluid leakages. In addition, chemical management procedures (e.g., containment ponds, dikes) should be able to control spillage and/or leakage. Thus, working/storage fluid contamination of area water supplies should not be a major environmental problem if this area of concern is given proper attention during the site development and system operation.

b. Lower Temperature Water-Based Fluids

Various additives may be used to control corrosion of the transport piping, pH levels, and/or biofouling. The release of these additives into area streams or groundwater could have significant effects. In addition, certain of these additives may potentially contaminate rural potable water supplies (discussed below). The additives of most concern and their potential impacts are presented here.

Chromates- Both chromate ($CrO_4^{-2}$) and dichromate ($Cr_2O_7^{-2}$) salts may be used as corrosion inhibitors in transport piping. Concentrations of chromates in working fluids would be on the order of 0.9 gm/l. The EPA maximum acceptable concentration of total chromium in raw water used for drinking water supplies is 0.05 mg/l.[13/] Dilution by a factor of 7,000 would bring the total chromium in the water to the EPA standard. If 10,000 gallons (37,900 liters) were emptied into a medium sized (10 billion gallon -- 37.9 billion liter) reservoir, dilution would amount to a factor of a million, thus yielding a level one hundred-fold below the standard.

Phosphates- Various phosphate solutions could also be used as corrosion inhibitors in system working fluids. Phosphorus is a key element in all living organisms. In the protoplasm of plants and animals it is broken down by cellular metabolism or the action of phosphatizing bacteria to dissolved phosphates (i.e., $CaHPO_4$). These dissolved phosphates may be utilized directly in protein synthesis in plants as primary nutrients.[14/] Thus, the release of relatively large amounts of phosphates can generally result in blooms of plankton and algae with consequent reductions in dissolved oxygen content from favorable levels of 2 to 3 mg/l. Concentrations are again expected to be small; however, release of large amounts of working fluids could result in possible discernable effects.

Nitrates, Nitrites- The general toxic effects of nitrates and nitrites in man and animals and their potential carcinogenic impacts have been discussed in the section on high temperature fluids. Typically, the nitrate-nitrogen concentrations in lakes and other impounded waters tend to be below 0.1 mg/l.[12/] This concentration could be exceeded if large distribution subsystems are flushed in the vicinity of wells and the discharge is allowed to infiltrate to groundwater.

In addition, nitrates, nitrites, and "fixed" (incorporated into chemical compounds) nitrogen in the form of ammonia are common basic nutrients in aquatic ecosystems. The release of these substances into lakes and rivers could stimulate floral growth resulting in the undesirable effects associated with eutrophication. The dissolved oxygen content of the water could thereby be reduced, with consequent harmful effects to fish. The concentration and thus the impacts of these substances are not expected to be serious, however, due to the volumes necessary to produce these effects at a noticeable level.

Sulfites, Sulfates- Certain sulfate solutions such as sulfuric acid and sulfide solutions such as sodium sulfide may be added to distribution fluids as pH controllers, biocides, and corrosion inhibitors. The sulfides can be decomposed to hydrogen sulfide ($H_2S$) by bacterial action, and the $H_2S$ is further oxidized to sulfates such as ammonium sulfate ($NH_3SO_4$).[14/] As in the case of phosphates, nitrites, and nitrates, sulfates are used by plants as primary nutrients. Related problems associated with eutrophication can result. In addition, the release of these substances could result in increased salinity and pH levels with possible harmful effects to aquatic life. The EPA maximum allowable concentration of sulfates in fresh water used for drinking water supplies is 250 mg/l, while the maximum concentration of sulfides for freshwater aquatic life is 0.0002 mg/l.[13] The levels of concentration evidenced in fluid transport subsystems, however, are not expected to pose significant problems.

The Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems (published jointly by the National Bureau of Standards and the Department of Housing and Urban Development) offer a series of guidelines for the proper containment and disposal of released liquid working fluids.[15] These guidelines are generally in relation to solar space heating systems, but they are also applicable in some cases to process heating. These guidelines require that:

1. A list of the chemical components of the heat transfer medium (i.e., the working fluid) must be provided in mg/l. This list must include any substances which comprise more than 0.10% of the medium;

2. The organic constituents of these substances must have a five-day biochemical oxygen demand (BOD), using sewage seed, of at least 70% of the theoretical oxygen demand. This test shall be in conformance with the Standard Methods for the Examination of Water and Wastewater, American Public Health Association (1971); and

3. The concentration of chemical constituents must be compared with the 96-Hour LC-50 (Lethal Concentration) bioassay value for protection of aquatic life. This comparison is to be made in accordance with the Water Quality Criteria, 1972.

Further research into chemical fluid additives is required in order to assess their potential impacts on water quality. Adoption of the above Minimum Property Standards (MPS) guidelines by local administrative and regulatory authorities should insure that fluids will not seriously impact the environment.

D. Land Use/Solid Waste

1. Foregone Uses of Land

Land use is an important consideration in solar deployment, primarily because of the relatively large land areas required for industrial applications. Industrial and agricultural process heating systems can require collector areas of up to one square mile (2.6 million square meters).

Process heating land requirements may thus conflict with alternative land uses or area land use plans. This would be especially true in commercial areas or areas of concentrated industry such as industrial parks. In such areas, land is at a premium and thus high in cost with conflicting claims as to its proper use.

To mitigate these potential conflicts, planning officials and the public should be educated on the relative cost-benefits and trade-offs between solar and fossil fuel heat generation. The relative land-intensiveness of solar heating is balanced by a number of factors. Among these are 1) it does not typically generate the solid wastes associated with fossil fuel-fired powerplants (e.g., ash) which require on or offsite disposal, 2) solar process heat is relatively non-polluting in terms of air, water, and thermal pollution, and 3) it conserves gas and oil for necessary high temperature processes. Thus, a case could be made for the benefits outweighing, or at least balancing, the costs in terms of relative land intensiveness and consequent displacement of other land uses.

Rural agricultural applications present a much smaller, but not a negligible impact on the availability of farm lands.

2. Backup Unit Residuals

Solar process heating systems may employ onsite fossil fuel-fired backup heater units for use during periods when direct solar radiation is not available. These units will generate the solid wastes (ash) typically associated with fossil fuel-fired equipment. Such wastes will require either on or offsite disposal. This problem is not peculiar to this approach, but is common to any fossil fuel-fired system. In addition, this problem is not expected to be significant owing to the relatively infrequent and intermittent use of the backup units and their probable use of oil or natural gas as fuels. The combustion of these fuels does not generally produce solid wastes in the same quantities as coal combustion.

E. Ecological Impacts

1. Working and Storage Fluid Release

As noted above, the various working/storage fluids used may be released into the environment as a result of flushing operations or leakage. The high temperature fluids, mainly hydrocarbon oils and eutectic salts, may potentially affect the ambient ecosystem. This is especially true for the oils, which may suffocate certain organisms by impairing the ability of surface cells to breathe. The salts appear to be somewhat less of a danger. Their release can be expected to result in increased soil salinity which may affect local soil communities. However, the impacts of increased salinity (and possible pH increase) due to salt solution release should not be significant owing to the localized nature of the emission. Proper containment measures (e.g., retention dikes) could also help alleviate this problem.

The effects of working/storage fluid release on the ecosystem would be insignificant if receded by the removal of vegetation and the paving or treating of the collector or heliostat field during plant construction. In addition, proper management and system maintenance should prevent their impacting local ecosystems. In this regard, flushed oils could be burned, recycled after treatment, or removed from the plant site and properly disposed of. Salts may be retained in catch basins until properly disposed of offsite in chemical dumps.

The impacts of low temperature fluids and additives on water quality and aquatic life have been discussed above. Low temperature transport fluid leakage could also potentially harm local flora and fauna. Proper containment facilities, such as catch basins, should prevent the release of these fluids from significantly impacting local ecosystems.

2. Collector Field Impacts

The collector units may produce significant shading effects which could potentially impact local ecosystems. Numerous floral and faunal species could be attracted to the shaded areas under these units where they may thrive, thus creating system imbalances and/or impediments to collector operation and maintenance personnel. Control of these shaded area microcommunities through various techniques may prove necessary. Paving or chemical treatment (oil application) for dust control purposes would eliminate floral growth as would the localized application of herbicides. In addition, the absence of floral growth and the presence of maintenance personnel should render the collector field undesirable as a faunal habitat.

## F. Safety Issues

Because of desirability, dependability, and maintenance cons erations, agricultural and industrial solar system appl cations are likely to result in system designs different from res ntial solar system applications. For industrial facilities with trained engineers onsite, it is likely that frequent maintenance activities will be performed if they are needed to ensure dependability. System failure will be less likely, but exposure to maintenance hazards will be more frequent. The training of plant personnel and their understanding of potential hazards should offset any increased potential for accidents. In addition, industrial systems are more likely (due to size) to be located at ground level or on flat roofs, thus eliminating having to work on a slanted roof during construction and maintenance.

Components of the solar system may also vary with the specific type of application. For intermittent applications, as in grain or forage drying, system components with high weathering durability but low performance durability may prove most economical. Peculiarities of design could result, and it cannot, therefore, be assumed that demonstration of the environmental acceptability of residential systems will ensure that industrial systems will be equally acceptable.

1. Contamination of Products

A specific concern, distinctive to the industrial and agricultural process heating use of solar energy, is the potential contamination of the commodities being heated. Whereas conventional process heating is based on gas, oil, or coal-fired furnaces or boilers operating at very high temperatures, the solar system is likely to operate at minimum necessary temperatures as low as 100-150°F (38-65°C). Such conditions for air-and water-based working fluids and storage media are conducive to the growth of fungi and bacteria not normally encountered in fossil fuel-fired heating. In the direct heating of products such as grain, tobacco, and food goods with solar-heated air, there is a potential for contamination which could lead to the spoilage of the product or the exposure of product consumers to these organisms. Bacterial fungal growths can be avoided through the use of biocides and/or the periodic flushing or clearing of the storage and working fluid equipment.

The use of biocides is related to a second area of potential contamination - that of chemical contamination of products. Solar heating systems utilize a variety of previously mentioned chemicals as working fluids, working fluid additives, and storage media. As mentioned in the discussions of potential water pollution, these substances can be harmful to livestock and humans consuming solar-heated or dried-food products. In addition, nonfood products such as textiles can be soiled or degraded. Contamination due to chemical exposure would only occur in the event of accidental spillage, leakage, or carry-over of materials into the process heating area. Such accidents can be avoided through the use of indirect heating (secondary work fluid systems) and/or through the careful monitoring of working fluids, processing area air or water quality, and the product itself. In addition, specific research is underway to develop heating systems and components which are nontoxic and unlikely to cause contamination.

2. Working Fluids: Safety and Handling

The compounds of concern in the eutectic salt mixtures are primarily the nitrite and nitrate salts of sodium or potassium. Their potential hazards are not encountered under normal operation, but under certain adverse conditions they can contribute synergistic effects to combustible materials in the event of a fire, increasing flammability and intensity. When exposed to temperatures above 716°F (380°C), sodium nitrate ($NaNO_3$) will decompose, releasing oxygen and forming sodium nitrite ($NaNO_2$) which will also decompose at high temperatures. At greater temperatures [around 1832°F (1000°C)] or when subjected to extreme shock, closed containers of substances can rupture or explode.[16]

These molten salt mixtures will not, under normal operation, be exposed to conditions that will cause their decomposition.

Their potential hazardous qualities, however, are manifested in their release of oxygen upon decomposition encountered under adverse conditions. In a worst-case example, it may be postulated that these nitrate compounds could become exposed to extremely high temperatures, as during a fire, rupture their containers, and fuel the intensity of an existing fire with oxygen (from decomposition).

In relation to oxidizing properties, sodium nitrate and sodium nitrite behave similarly (the potassium nitrate/nitrite analogs are similar to the sodium compounds and therefore need not be discussed). When accompanied by combustible materials, $NaNO_3$ and $NaNO_2$ pose a severe fire hazard. Generally, nitrate-flammable mixtures require an ignition source before they burn; however, once ignition occurs, violently rapid combustion [16/] is possible, even explosion. Indeed, sodium nitrate is such a powerful oxidizer (or oxygen carrier for reactions) that it is used in straight dynamite. Fire problems are further compounded by the release of nitrogen oxides accompanying the decomposition of the nitrates and nitrites. These oxides are toxic, and self-contained oxygen gear must be worn when fighting a nitrate-nitrite-induced fire.

Storage and handling of $NaNO_3$ and $NaNO_2$ must also be done with prudence as they are hygroscopic compounds which absorb moisture either from the air or material they contact, thereby increasing the potential for combustion. Again, proper handling practices are well-documented and, under these conditions, $NaNO_3$ and $NaNO_2$ are safe.

Hydrocarbon oils can also pose a potential fire or burn hazard. At temperatures of approximately 356°F (180°C) the oil vapors will combust if exposed to air (this is known as the "Flash Point"). The "Fire Point," at which the liquid oil itself will combust, is typically at temperatures of approximately 381°F (194°C).[17/] These hydrocarbon oils also represent a hot medium and will cause severe burns if they come in contact with the skin.

Under normal operating conditions, heated hydrocarbon oils will not be exposed to air and thus combustion should not occur. Proper system maintenance should prove adequate to control possible leaks of heated oil which could result in oil fires. In addition, proper handling and protective gear should prevent serious burns. The hydrocarbon oils being considered for process heating applications are not new, but rather have been in industrial use for quite some time. Thus, fire and burn safety procedures and proper handling techniques are generally well understood and thus fairly easily employed at solar installations.

3. Worker Safety

Because solar energy systems will comprise fairly sophisticated technologies, professional engineering support will be required of the operator. Thus the potential for accidents due to inexperience or lack of understanding will be lessened. However, education of the work force concerned as to the potential safety hazards of solar process systems should be undertaken to insure safe operation and minimize accidents or injuries.

G. Esthetics

The visual effects of solar process heating will vary greatly, depending upon their specific uses. The greatest visual impact will be the collector and storage system. Both will present a unique and unfamiliar appearance. In industrial areas, the plant will generally fit in well, appearing as an industrial installation of some sort. In residential or rural areas, however, the plant will contrast markedly with surrounding scenery.

## SECTION IV

## NEPA DOCUMENT WORK PLAN AND ENVIRONMENTAL RESEARCH PROJECTS

### A. Introduction

The purpose of this section is to lay out a preliminary draft work plan for environmental analysis of the solar process heating system concepts under development by the Energy Research and Development Administration. It addresses the preparation of Environmental Development Plans, Environmental Impact Assessments, and Environmental Impact Statements as well as the conduct of basic and applied research supportive of developing a better understanding of the environmental attributes of solar process heating.

The work scheduled in this report should not be construed as official plans of either the Division of Solar Energy or of ERDA as a whole. The work shown is that identified by the contractor. Many of the projects identified and outlined in Section D can be carried on outside of ERDA and can be handled in a variety of ways. The scheduled work does not take into account breakthroughs or findings which may allow for significant reductions in effort or expansions, and it may not reflect specific work already underway in the public or private sectors.

### B. Description of NEPA Documents

#### 1. Background

The National Environmental Policy Act of 1969 (NEPA) implemented by Executive Order on March 5, 1970, and the guidelines of the Council on Environmental Quality of August 1, 1973, require that all agencies of the Federal government prepare detailed environmental statements on major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the Federal agency decision-making process, at the earliest possible point, an appropriate and careful consideration of all environmental aspects of a proposed action in order that adverse environmental effects may be avoided or minimized.

In carrying out this mandate, each agency of the government has set out a policy and procedures for implementing these requirements. The ERDA currently operates under official guidelines originally established by and for the now defunct Atomic Energy Commission. In an effort to update and reorient the guidelines to meet ERDA's need, alternative guidelines are now being prepared within ERDA.

Although the proposed revisions have yet to be finalized or adopted, because the proposed changes are so extensive and this document is to serve as an input to a future agency planning effort, for purposes of this analysis the most recent proposed revision (November 1, 1976) has been used to represent the future official guidelines. The discussion of NEPA report requirements and recommended work schedule is predicated on the guidance provided in the November 1 draft revision.

The backbone of ERDA's NEPA compliance program is the preparation and review (by the agency and the public) of documents addressing the environmental aspects of programs and projects of the agency. Three types of documents are particularly important. These are Environmental Development Plans (EDP's), Environmental Impact Assessments (EIA's), and Environmental Impact Statements (EIS's). Each is described below.

2. Environmental Developmen[illegible] Lans.

An Environmental Development Plan (EDP) is the basic ERDA management document for the planning, budgeting, managing, and reviewing of the broad environmental implications for each energy technology alternative for each major ERDA research, development, and demonstration and commercialization program. The EDP is designed to identify environmental issues, problems, and concerns as early as possible during the program's development, to analyze the available data and assess the current state of knowledge related to each issue, problem and concern, to set forth strategies to resolve these, to set forth the processes by which the public is involved in identification and resolution of these issues, problems, and concerns, and to designate significant milestones for resolution of these issues, problems, and concerns. The timing of the EDP's milestones reflects the sequencing of the technology development. The EDP's, once completed, are made available to the public.

3. Environmental Impact Assessments

An Environmental Impact Assessment (EIA) is a written report prepared by an ERDA program office, which evaluates the environmental impacts of proposed ERDA actions to assure that environmental values are considered at the earliest meaningful point in the decision-making process and, based upon the evaluation, it determines whether or not an environmental impact statement should be prepared. The EIA is intended to be a brief, factual, and objective document describing the proposed action, the environment which may be impacted, the potential environmental impacts during construction, operations, and site restoration, potential conflicts with Federal, State, regional, or local plans, and the environmental implications of alternatives.

4. Environmental Impact Statements

An Environmental Impact Statement (EIS) is a document prepared at the earliest meaningful point in the decision-making process which analyzes the anticipated environmental impacts of proposed ERDA actions and of reasonably available alternatives. It reflects responsible public and governmental views and concerns. EIS's are prepared in response to plans in the program EDP or after the review of an EIA which identifies potentially significant impacts. The EIS goes through a specific preparation process involving agency and public review.

The EIS goes through four steps during its preparation. The preliminary draft is reviewed within ERDA; the draft is distributed to the public for review and comment; the preliminary final incorporating comments submitted to ERDA in response to the draft is reviewed within ERDA; and the final EIS is issued reflecting the agency's final review and deliberations. This final EIS is then officially filed with the Council on Environmental Quality and distributed to the public. Except in special cases, no ERDA action subject to EIS preparation can be taken sooner than 30 days after the final EIS has been issued.

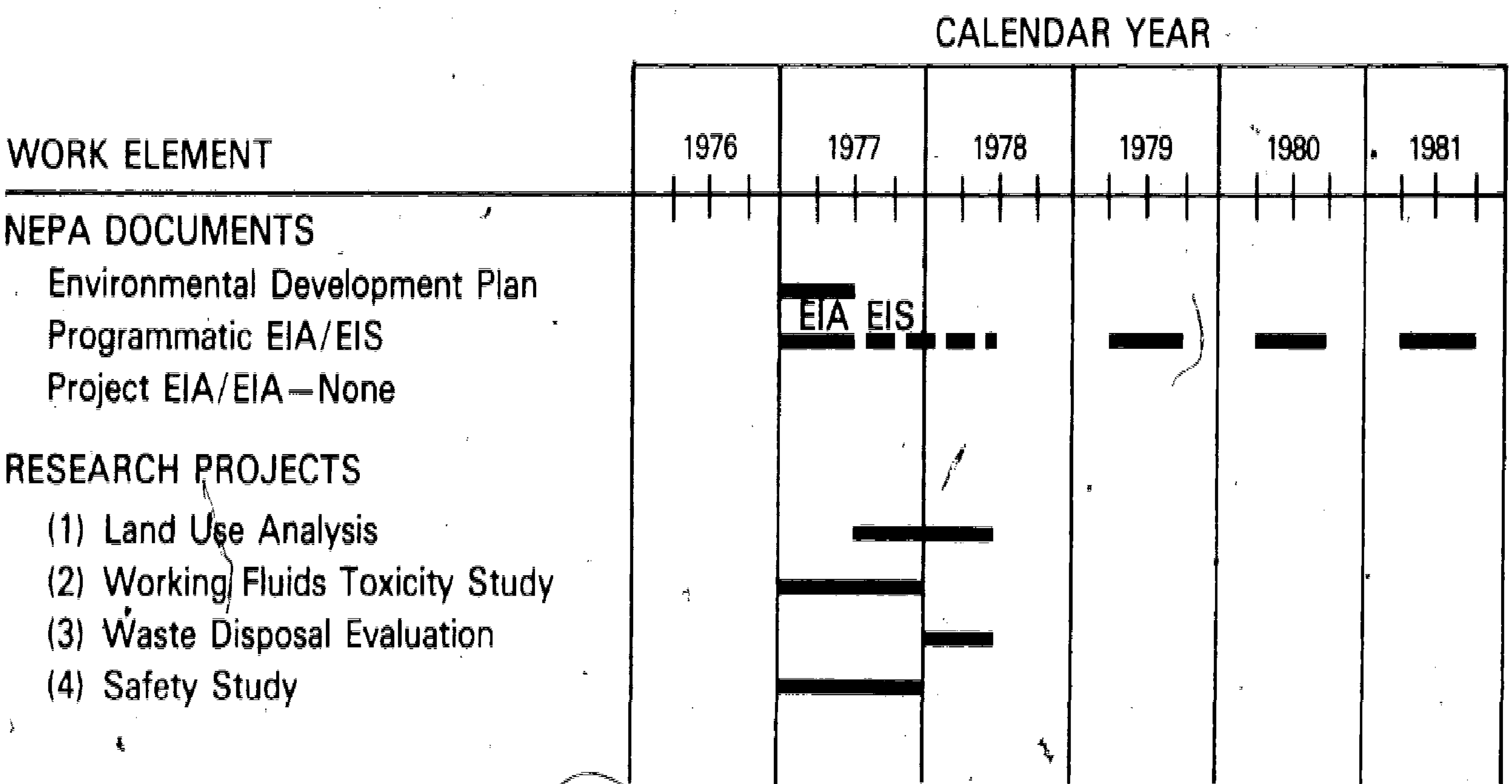
EIS's can be prepared covering programs, projects, or the use of ERDA facilities. In each case the document must reflect the utilization of a systematic interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts.

Contents of the report cover a description of the proposed action and alternatives, a description of the existing environment, an analysis of environmental impacts of the proposed action and its alternatives, and a specific review of the unavoidable adverse effects, resource use, land use implications, and the environmental trade-offs represented by the proposed action and the alternatives.

C. NEPA Document Work Plan

Figure IV-1 presents an environmental work schedule for various solar process heating projects. Also included is a schedule for various research projects which are proposed below.

FIGURE IV-1
AGRICULTURAL AND INDUSTRIAL PROCESS HEAT ENVIRONMENTAL WORK SCHEDULE



D. Research and Development Projects

Through the preparation of EEA's environmental survey of the ERDA solar process heating program, a wide range of environmental issues were identified which could not be adequately analyzed within the context of this study due to the complexity of the problems, the general lack of necessary research data, and the level of effort and schedule of the EEA study. This section identifies specific follow-up research projects which the EEA staff felt were critical to the understanding of the environmental consequences of large-scale deployment of solar heating systems and which are not likely to be specifically or adequately addressed solely in the preparation of NEPA documents. Many other research projects were identified during EEA's study. This list represents a condensation and trimming down of draft lists to those projects which are felt to be of greatest importance to the advancement of solar process heating use and the associated decision-making process within the Federal government. Because process heating involves the application of technologies used in home heating and cooling and thermal electric systems, some of the projects identified below are intended to produce data useful in assessing these as well as process heating impacts.

1. Land Use Alternatives Evaluation for Candidate Sites

- Working with ERDA personnel and researchers, identify specific siting locations representative of major deployment of the process heating methods;
- Estimate and map out the specific land use requirements of the facility at each site; and
- Identify current and projected (1990) land use or land use alternatives for each site and evaluate the economic and social impact implied by use of the sites for solar process heating.

2. Liquid Working Fluid Additives Toxicity/Contamination Analysis

- Survey all working fluid additives to identify chemical composition and range of concentrations likely to be found in water-based working fluid, and reason for using additive;
- Analyze various paths for entry of working fluid into the groundwaters and/or the individual domestic water supply and estimate possible concentrations in the drinking water supply;
- Review effects information to determine type of effect and severity of single or multiple doses incurred prior to detection of the leak (due to water taste or system failure); and
- For those contaminants which present a risk, evaluate control strategies which might include:
  - -- taste or color indicators of a leak;
  - -- a leak detection system;
  - -- redesign to prevent leaks from occurring; and
  - -- elimination of additive or use of an alternative additive.

3. Solid and Liquid Waste Disposal

- Analyze alternative methods for treatment and disposal of used storage salts and working fluid removed from the heating systems during maintenance or repair; and
- For each approach estimate cost, labor required, and the net environmental impact and whether regulatory or financial incentives will be needed to insure adequate implementation.

4. Labor Training and Safety

- Characterize the existing labor force (size, training, location, union structure) of the process heating system installation and maintenance industries;

- Determine how the labor requirements for solar process heating installation will change (shift, expand) the current labor force in this area;

- Examine the skill requirements and worker safety precautions necessary for solar process heat installation and the effectiveness of various learning methods in conveying this knowledge to current members of the process heating labor force or to new members of this labor force; and

- Given the projected growth of solar process heating, assess the likelihood of having an adequately trained and protected labor force and if appropriate examine alternative mechanisms available to the Federal government to insure that a sufficiently trained labor force will develop.

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