CONF-800706--2

363
6/9/80
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SERI/TP-733-693
UC CATEGORY: UC-59b

DR. 1286

APPLICATIONS OF SOLAR ENERGY IN INDUSTRIAL PARKS

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MAY 1980

PRESENTED AT THE
1980 WESTERN PLANT ENGINEERING
CONFERENCE, JULY 15-16-17
ANAHEIM, CALIFORNIA

PREPARED UNDER TASK NO. 3473.40

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

Prepared for the
U.S. Department of Energy
Contract No. EG-77-C-01-4042

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Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price:
Microfiche $3.00
Printed Copy $4.00

NOTICE

APPLICATIONS OF SOLAR ENERGY IN INDUSTRIAL PARKS

Introduction

Industrial parks incorporate a growing portion of the industrial sector. This paper presents the four phases of ongoing work at SERI that examines many unresolved questions regarding the purpose, solar applicability, economics, and energy modeling of these parks. The first phase involved site visits to approximately 300 parks in 12 major metropolitan areas of 9 states. These parks ranged from office complexes to heavy industrial zones. This analysis focuses on medium-sized industrial parks (100-500 acres) because they represent the majority of parks visited. Characteristically, the tenant mix of these parks is predominately light to medium manufacturing with some warehouses.

Phase 2 entails an analysis of four industrial parks selected from those parks surveyed. The selection criteria is based on standard attributes and potential for solar access. The completion of this ongoing phase will produce detailed process energy data for at least five industrial tenants and space conditioning requirements for one commercial tenant in each park.

The focus in Phase 2 is narrowed in Phase 3 to two parks to be examined for detailed technical and engineering analysis. Energy conservation potential and major solar technologies are included in this analysis.

Phase 4 incorporates all of the work of the earlier phases with economic criteria provided by the park realtor and the manufacturing management. The product is an energy allocation model describing energy delivery and consumption within the park. Sensitivity of the model's cost minimization function can be measured by the effects of economic policy, rising fuel cost, and fuel availability.

Background

The concept of dedicating specific areas to planned industrial development evolved nearly a century ago in Great Britain [1]. Although many industrial sites erroneously adopt the term "park", a true industrial park presently must meet a set of criteria developed by the National Association of Industrial Parks. The purpose of an industrial park is to "improve the techniques and practice of zoning as applied to land for industry as part of comprehensive community planning" [2]. Complete preconstruction planning should include availability of water and fuel supply lines, accessability of transportation, building setback and landscaping details, and designated restriction of nuisances (e.g., noise, vibration, dust and dirt).

Solar Energy Applications

Incorporating solar energy applications into industrial parks is important in industrial process heat. Industrial parks are prime areas for initial alternative energy impact in the industrial sector for the following reasons:

- lead-time for design and zoning is usually 3 to 5 years prior to the actual groundbreaking for the park,

- there are large landscaped areas, and
- building height and setback requirements are uniform.

Long lead-time before construction offers several advantages for solar systems for parks currently in the planning stages. Conservation measures can easily be incorporated into buildings under construction with little additional cost. In addition, passive solar buildings (which maintain the space conditioning of the structure) can be designed as readily as traditional structures. Active solar systems for process heat applications can be located on the ground, roof, or side of a structure. Although present building practices limit roof and building side sitings, the lead-time should allow for construction of more struts for roof mounted arrays, development of lighter panels, or incorporation of the panels into the south-facing structure wall. The availability of land areas with sites greater than 25 acres permits the favorable positioning of centralized or decentralized solar systems. Uniformity of building height minimizes shading. The set-back requirements reduce the possibility of breakage of equipment (i.e., collector glazing) by road gravel and other hazards.

In essence, the planning and timing for construction of industrial parks accommodates the development of improved reliability for solar technologies in testing facilities today. Present costs of solar technologies exceed costs for conventional equipment and the corresponding fuels. Not only do solar technologies have higher costs, but in addition, they are not able to satisfy the demand currently met by conventional technologies, provided the fuel is available. Anticipated increased annual production rates of solar equipment should increase its reliability and lessen this cost considerably. The rising prices of fossil fuels are also expected to diminish the cost gap between conventional fuels and the competing solar technologies.

Because process heat is a major portion of the energy consumed within a park, process temperature ranges must be known to be matched with solar technologies. The distribution of process temperatures is imprecise for a specific SIC (Standard Industrial Classification) code or for the manufacturing sector. Until recently, the best temperature distribution available was calculated by InterTechnology Corporation (ITC) [3].

The distribution presented in Table 1 is a revision of the ITC work reflecting reallocation of metallurgical coal to feedstock, of actual required temperature rather than those temperatures at which heat is produced, and of estimates in other ranges based on more recent studies [4]. All estimates must be considered provisional due to ongoing technological changes in industrial processes.

Established thermal solar technology can attain temperatures from 350° to 550°F (176° to 287°C). Developing technologies are expected to have the capability of producing heat up to 2000°F (1093°C).

Designing one solar energy system applicable to all parks would be ill-advised at present. However, the design for a specific park should incorporate the following topics:

- centralized system versus decentralized systems,
- thermal versus electrical subsystems,
- energy storage versus no storage, and
- climatic conditions.

Table I. ESTIMATED TEMPERATURE RANGE DISTRIBUTION OF INDUSTRIAL PROCESS HEAT DEMAND

Temperature Range (°F)	Quads (1×10^{15} Btu)	Percentage
under 212	0.96	7.9
212-350	3.54	29.0
350-550	2.75	22.6
550-1100	2.50	20.5
1100-2000	0.96	7.9
over 2000	1.48	12.1
Total	12.19	100.0

A centralized thermal system requires sufficient area close to the end users. This central location may result in lower installation, training, and maintenance costs. Although a central system may be easier to monitor than several small systems, energy allocation may be more difficult to control if there is large variance in the weekly load profiles of the several industrial users. A decentralized system may be better suited to a park if the required process temperatures vary greatly between users.

Decentralized systems do not require single large centralized portions of land and can be more closely matched to the weekly load profile of a particular user. Shorter piping runs, used in decentralized systems, are critical in solar designs for reduction of thermal losses and lowered cost. Several small systems instead of one large system also increases the reliability of supplying solar energy to the industrial park. The disadvantage of several small systems is potentially higher initial training, and maintenance costs.

Thermal versus electrical subsystems will be analyzed based upon the type of load to be met and the interface required with existing equipment. These subsystems will consist of collection, distribution, and storage. Centralized electrical systems do not require close proximity to the end user.

The complex decision whether to include storage should be dependent upon the weekly load profile. Constant daily operation during the week may preclude the use of storage. Two shifts a day on a 5- or 7-day weekly basis might favor storage utilization to provide partial energy for the second shift. For a 5-day operation schedule, weekend collection could boost energy use in the following week. One shift per day may provide sufficient load for storage depending again on weekend utilization.

Climatic conditions may favor the selection of certain solar energy technologies. Direct radiation is required for concentrating collectors, while flat-plate collectors use diffuse radiation as well as direct radiation. Wind turbines require an adequate wind regime. Blowing sand, saltwater, or pollution can affect the performance of solar energy equipment.

Solar Energy Technologies

The following solar energy technologies suitable for parks: are described with their potential applications

- thermal collector systems,
- photovoltaics,
- biomass,
- solar ponds,
- wind, and
- central receivers.

Currently, there are numerous thermal collector types that may be applied to the process or space heating needs of an industrial park. Conventional flat-plate collectors can typically provide temperatures up to 212°F (100°C)—suitable for building heating, low temperature end-use processes, and preheat water. Flat-plate collectors are especially applicable when little open space is available because collectors may be installed on rooftops. Parabolic trough collectors operate at higher temperatures ranging from 150° to 550°F (65° to 287°C) and thus can provide quality end-use energy for many industrial processes. Both flat-plate and parabolic trough collectors may be used as decentralized or centralized energy sources.

In addition to these active systems, several passive technologies may be incorporated into industrial parks. For example, heating a warehouse with a southern exposure could be accomplished by a trombe wall retrofit on the structure. Because heating requirements and temperature swings are not critical for storage and distribution centers, passive designs may be the most appropriate.

Photovoltaic power systems are another alternative energy source for industrial parks. Photons from sunlight are converted directly into electricity by solar cells composed of semiconductor materials. The electrical energy then may be converted to AC and used immediately or stored in batteries. An advantage of this system is that the electricity may be used to produce any end-use temperature, or to power equipment. The photovoltaic cell is expensive to produce; therefore, a photovoltaic system cannot economically compete with many other solar technologies at present. However, a national research effort is underway to lower the cost.

Biomass is organic material such as manure, crops, and seaweed. Energy conversion occurs by a thermochemical process (direct combustion, gasification, pyrolysis or liquefaction) or by biological conversion (anaerobic digestion or fermentation). Steam, gas, heat, and electricity are all possible end-products. The conversion process could then occur on a batch basis or directly fired according to the required process needs. Intermittent weather problems common to solar systems are easily avoided with renewable and interchangeable sources of biomass fuel. An industrial park desiring to use biomass could dedicate greenbelt areas to biomass crop production or could purchase rights to nearby forest or agricultural residues.

A solar pond serves two purposes: collection of solar energy and thermal storage. High concentrations of salt at the bottom with decreasing levels of salinity toward the surface counteracts the tendency for thermal buoyancy convection, and thus prevents primary heat loss of the pond. Typical storage temperatures in a solar pond range from 122° to 194°F (50° to 90°C) [140° to 158°F (60° to 70°C) annual average], depending on the pond design, local climate, load profile, and the time of year. A solar pond could be sited on greenbelt land of an industrial park, and used to provide heat to one or several tenants of the park. Additionally, recent advances in low-temperature organic Rankine-cycle turbines make the production of electricity using solar ponds a viable alternative.

Because it is primarily caused by unequal heating of the earth's surface by the sun, wind is considered a solar technology. Wind turbines require obstruction-free locations with dependable wind conditions. The electricity generated by a wind turbine can be fed into a utility grid or easily stored during periods of low demand. Installing one large or several small wind turbines to roughly match the load profile with the wind energy profile is advantageous since this maximizes the use of the wind energy and displaces the greatest amount of utility-bought energy. Wind turbines could potentially complement a solar thermal collector system by providing energy during cloudy days.

The central receiver or power tower operates when direct radiation is focused on a tower receiver by heliostats or mirrors. The operating fluid then may be heated to 2000°F (1093°C) and converted to electricity by a steam turbine. Preferable siting of a power tower would be where it could benefit both a utility and/or several parks. A central receiver can supply both electrical and thermal energy, although it is limited to locations with more direct than diffuse radiation.

Energy Model

The focus of this work, including the phases already discussed and the addition of economic options for the park scenario, is to develop a mathematical model. The model will use designated data from any industrial park in combination with a program, not discussed here, using climatic, load profile, and solar performance data to produce least cost energy allocation and the respective sensitivity to prices, policy and availability.

This linear programming model is structured as a generalized transportation problem and will perform the function of energy allocation. This formulation incorporates the essence of the industrial park by satisfying industrial end-use demands without exceeding available fuel supplies. The objective of this model is to minimize the cost of supplying conventional fuels and solar technologies to the industrial process heat, mechanical drive, space conditioning, and other requirements.

This energy model is basically the same as a distribution problem within a manufacturing firm. The factories produce several different products, and the warehouses must stock these products in varying quantities to satisfy the customers. Economic questions such as product transportation, feedstock cost, production capacity, and product cost and related market demand can be answered by the model.

In conclusion, the potential of solar energy applications to support the energy needs of industrial parks warrants close examination. Future work on this project, will entail optimization analysis by mathematical methods to provide an analysis of economic sensitivity to assure better performance and cost effectiveness.

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Document Control Page	1. SERI Report No. TP-733-693	2. NTIS Accession No.	3. Recipient's Accession No.

4. Title and Subtitle
Application of Solar Energy in Industrial Parks

5. Publication Date
May 9, 1980

6.

7. Author(s)
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8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

10. Project/Task/Work Unit No.
3473.40

11. Contract (C) or Grant (G) No.
(C)
(G)

12. Sponsoring Organization Name and Address

13. Type of Report & Period Covered
Technical Publication

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)
Paper presents the four phases of ongoing work at SERI that examines many unresolved questions regarding the purpose, solar applicablility, economics, and energy modeling of industrial parks. The first phase involved site visits to approximately 300 parks in 12 major metropolitan areas of 9 states. Phase 2 entails an analysis of four parks selected from those parks surveyed. Phase 3 narrows the focus to two parks to be examined for detailed technical and engineering analysis. Phase 4 incorporates all of the work of the earlier phases with economic criteria to produce an energy allocation model describing energy delivery and consumption within the park.

17. Document Analysis
a. Descriptors Industrial Parks ; Solar Energy ; Economics ; Statistical Models ; Industry ; Solar Thermal Energy Conversion ; Photovoltaic Energy Conversion ; Wind Energy Conversion Systems ; Central Receivers ; Biomass
b. Identifiers/Open-Ended Terms

c. UC Categories
59b

18. Availability Statement
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

19. No. of Pages
8

20. Price
$4.00

Form No. 8200-13 (6-79)

☆GPO:1000—077-175/120