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Project Summary

Solar Energy for Pollution Control

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A study was conducted to determine which existing or emerging pollution control processes are best suited to make use of solar power and to determine the potential benefits of such applications. Pollution control processes were matched with compatible solar energy systems, resulting in the following four combinations:

- **Anaerobic digestion /flat-plate collector**
- **Anaerobic digestion/parabolic trough concentrator**
- **Baghouse heating/parabolic trough concentrator**
- **SO_x scrubbing/parabolic trough concentrator**

These combinations were analyzed for potential nationwide fossil fuel displacement and cost effectiveness. Based on the results of this survey and the supporting analyses, solar energy applied to sludge heating for anaerobic digestion would result in the greatest fossil fuel displacement at the lowest specific cost among the various pollution control applications investigated.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

A number of pollution control processes require significant input of energy, which is typically supplied by fossil fuel. The result is that the overall effectiveness of each pollution control process is decreased by an amount equal to the pollutants generated during combustion of the fossil fuel. Solar energy provides a possible means for delivering clean energy to the process load and decreasing the amount of fossil fuel required. The energy requirements of many pollution control processes could be met by solar energy systems using currently available technology and off-the-shelf hardware, at costs similar to those of existing solar heating and cooling systems.

A study was undertaken to determine which existing or emerging pollution control processes are the most compatible with solar energy systems, and to determine the potential benefits of such applications. The study was conducted in three parts:

1. Survey of pollution control processes to determine which are most compatible with the relevant solar technologies.
2. Prioritization of relevant pollution control technologies in terms of potential fossil fuel savings.
3. Determination of the most cost-effectiveness pollution control/solar energy system combinations.

The solar energy technologies considered by this study included those available off-the-shelf for supplying thermal energy for process heating and cooling. A general solar system schematic shown in Figure 1 was developed to allow substitution of major system components to meet the requirements of each pollution control process. The system includes an interface with the process streams by means of a simple heat exchanger. The two major components which are specific to the solar energy system are the collector and the thermal storage medium. Flat plate and concentrating collectors were analyzed in this study. The two methods of thermal storage which are currently commercially available were considered: sensible heat and latent heat.

Once potential combinations of pollution control processes and solar energy systems (PCP/SES) had been identified, they were analyzed individually for potential nationwide fossil fuel displacement and cost effectiveness. Fossil fuel displacement was first determined on a regional basis. Regions were defined by their isolation rates, and system sizing, performance and fossil fuel savings were determined for each region. The total fuel savings in a region was the product of the savings at a typical plant using the pollution control process and the number of plants in that region. The nationwide fossil fuel displacement for the process was determined by summing the fuel savings for each region.

The cost effectiveness of these candidate PCP/SES combinations was also considered. For the purpose of this study, cost effectiveness is described in terms of specific cost of a solar energy system ($/unit energy displaced). The specific cost was calculated by dividing the life cycle of the system by the annual fossil fuel displacement cost by the solar system. The after tax Life Cycle Costs (LCC) were calculated based on the following formula:

$$LCC = CRF\,(1 - ITC)\,(C) + (1 - t)\,OC - t\,(D)$$

where

CRF = capital recovery factor, i = 10 percent, n = 20 years

ITC = investment tax credit = 10 percent

C = capital costs

t = weighted federal and state tax rate = 50 percent

OC = tax deductible operating costs

D = depreciation, straight line.

Fossil fuel displacement was taken as equivalent to the energy supplied to the pollution control process by the solar energy system minus the energy required to operate the solar energy system (e.g., for powering circulation pumps).

Conclusions

Three pollution control processes were identified as most compatible with the relevant solar technologies. They are:

- Sludge heating to promote anaerobic digestion.
- Baghouse heating for prevention of acid condensation during shutdown.
- Flue gas reheat for SO_x scrubbing.

Figures 2, 3 and 4 show the three pollution control technologies, the operating temperatures associated with each, and the possible interface points for a solar energy system.

The three processes were matched with compatible solar energy systems, resulting in the following four combinations:

- Anaerobic digestion/flat-plate collector
- Anaerobic digestion/parabolic trough concentrator
- Baghouse heating/parabolic trough concentrator
- SO_x scrubbing/parabolic trough concentrator

In order to keep collector outlet temperature and storage volume at a minimum, the stratified thermal storage concept was chosen. It was found that unpressured storage vessels were appropriate for the anaerobic digestion and gas reheat PEP/SES combinations. For the baghouse/parabolic trough combination, a 655KPa (95 psia) pressure vessel was required.

The fossil fuel displacement analysis revealed that parabolic trough line concentrators applied to sludge heating to promote anaerobic digestion in municipal wastewater treatment plants would have the greatest impact on fossil fuel savings. Approximately 67.3 PJ (0.064 Quads) could be saved each year in this pollution control process. Flat-plate collectors applied to the same process would yield slightly less savings. The overall prioritization of pollution control/solar energy system pairs on the basis of potential fossil fuel displacement was as follows:

1. Anaerobic digestion/concentrator 67.3 PJ (0.064 Quads)

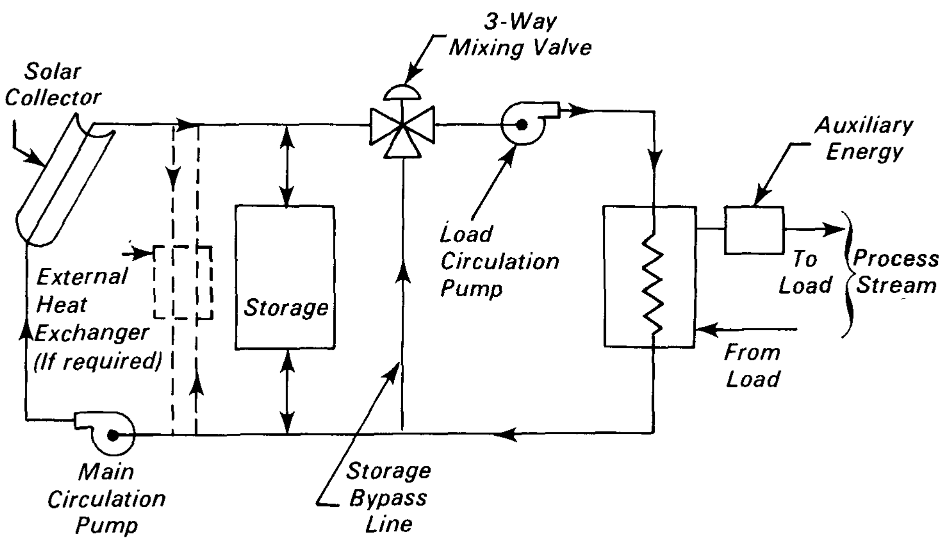

Figure 1. Schematic of basic solar energy system.

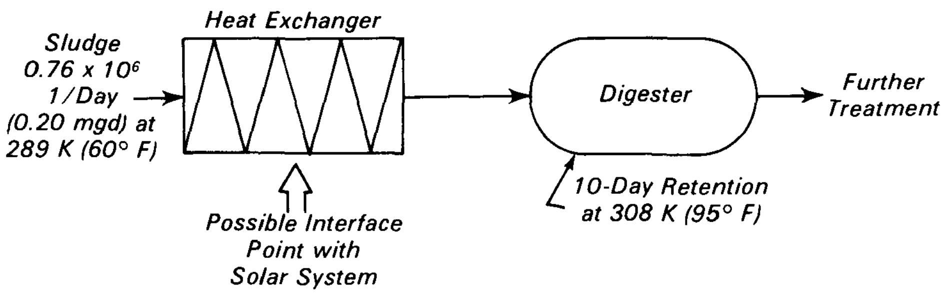

Figure 2. *Flow diagram for anaerobic digestion for a typical 0.76 x 10^6 1/day (0.20 mgd) treatment plant.*

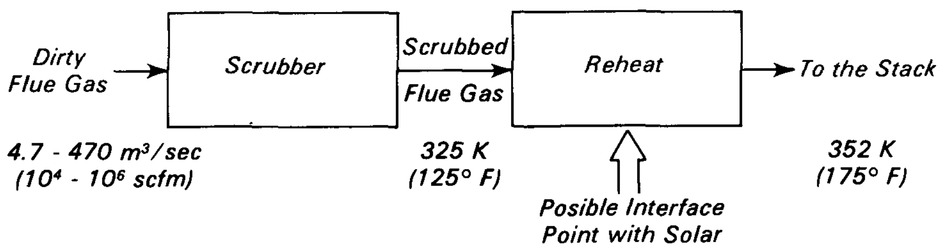

Figure 3. *Flow diagram of the flue gas reheat for SO_X scrubbing.*

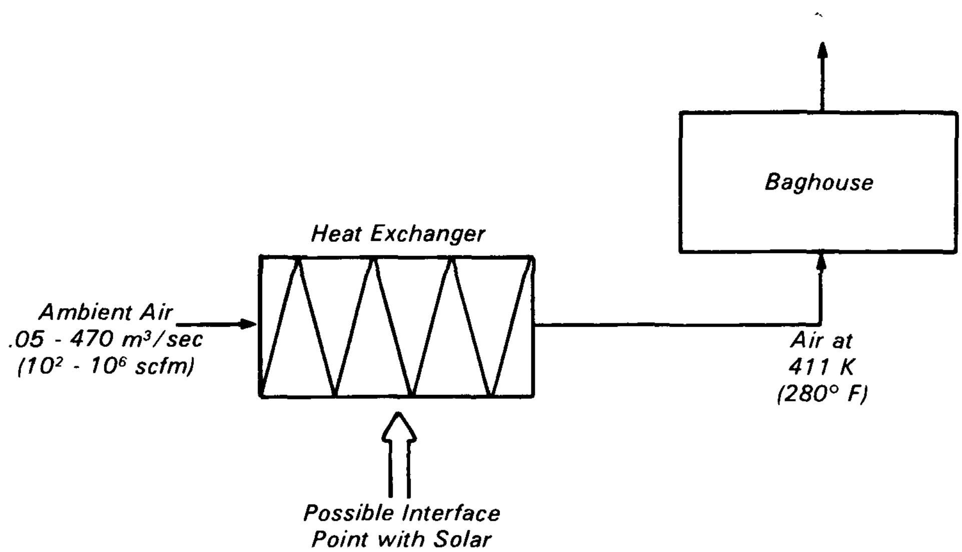

Figure 4. *Flow diagram of baghouse heating during shutdown.*

2. Anaerobic digestion/flat-plate
   66.7 PJ (0.063 Quads)

3. Baghouse heating/concentrator
   7.9 PJ (0.0075 Quads)

4. SO_x scrubbing/concentrator
   0.5 PJ (0.0005 Quads)

Based upon these results, a ranking of the pollution control processes in terms of potential fossil fuel displacement is straightforward. It is as follows:

1. Sludge heating for anaerobic digestion
2. Baghouse heating
3. SO_x scrubber flue gas reheat

There are several reasons for anaerobic digestion having a clear advantage over other processes. Wastewater treatment plants are needed all over the country and will grow with population. The lower temperature requirements are also attractive from the point of view of collector performance, and give the process a great cost advantage. An additional benefit of using solar energy for sludge heating for anaerobic digestion is that it will free the digestor gas produced by the process for other uses.

Besides the low energy savings, there are several technological drawbacks to using solar energy to heat baghouses for flue gas reheat. First, there are some significant problems associated with installing solar energy systems on plants using baghouses and SO_x scrubbers Both baghouse and SO_x scrubbers are installed in plants producing high levels of particulates and other contaminants in the air. Keeping solar collectors clean for maximum performance would be difficult and would certainly add to the life cycle cost of the system. Furthermore, many of these units are installed at power plants, where adequate collector siting areas would be difficult, if not impossible, to obtain.

The cost-effectiveness analysis indicated that the anaerobic digestion/concentrator combination would be the most attractive, on the basis of specific cost. For a cost would range from $7.59 to $17/GJ ($8.01 to $18 13/$10^6$ Btu), depending on location, with the lowest specific cost referring to locations of greatest isolation. Flat-plate collectors applied to anaerobic digestion also look promising, having specific costs in the range $7.91 to $22.2/GJ ($8.34 to $23.4/$10^6$ Btu).

Based on these analyses, solar energy applied to sludge heating for anaerobic digestion results in the greatest fossil fuel displacement at the lowest specific cost among the various pollution control applications investigated. The only other PCP/SES combination which looks promising is the anaerobic digestion/flat-plate system. Both the baghouse heating and SO_x scrubber reheat applications do not look attractive because of generally higher specific costs and other, technology-specific, shortcommings associated with each of them.

Recommendations

Several pollution control technologies which could potentially utilize solar energy were not considered in detail in this study because of a lack of sufficient technical data. These included carbon regeneration for activated carbon adsorption, drying of sludge for composting, heat treatment of sludge, Carver-Greenfield oil emersion dehydration, and waste pyrolysis. Further analysis of the potential of interfacing solar energy collectors with these systems is recommended.

Of the PCP/SES combinations analyzed in depth in this study, the most cost-effective are those in which solar thermal energy is supplied for anaerobic digestion. It is recommended that an investigation be conducted to assess in greater depth the practicality of installing solar energy systems at specific anaerobic digestion facilities in the United States. The investigation should be conducted in two parts:

- Survey existing wastewater treatment plants and assess specific applicability of solar energy.
- Prepare design manual for applying solar energy to wastewater treatment plants.

Survey and Assessment of Solar Applicability

Data to be gathered in the survey include isolation, specific process energy requirements, duty cycles and interface requirements. After a screening process, these data should be used to formulate feasible solar energy system conceptual designs for selected wastewater treatment plants. The conceptual designs should serve as the bases for detailed performance and economic analyses. If available, installation, maintenance and operation cost information from an operational solar-assisted wastewater treatment plant should be included in the data base for the economic analyses. Finally, areas in which costs can be reduced should be identified in order to obtain cost competitiveness of solar energy systems with conventional power systems.

Solar Energy Design Manual for Wastewater Treatment Plants

Based upon the results of the above task, a design manual for applying solar energy to wastewater treatment plants should be prepared. The manual should provide solar application guidelines to help design, construct, operate and maintain plants for communities of various populations. The manual should include solar energy system design guidelines for sludge drying and space and hot water heating in addition to anaerobic digestion.

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The complete report, entitled "Solar Energy for Pollution Control," (Order No. PB 82-116 658; Cost: $12.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
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