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TITLE: THE COMPARATIVE ECONOMICS OF PASSIVE AND ACTIVE SYSTEMS: RESIDENTIAL SPACE HEATING APPLICATIONS

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THE COMPARATIVE ECONOMICS OF PASSIVE AND ACTIVE SYSTEMS: RESIDENTIAL SPACE HEATING APPLICATIONS*

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ABSTRACT

As the interest in solar energy applications for residential space heating grows, it becomes imperative to evaluate the economic performance of alternative designs. We concentrate on one passive design--the thermal mass storage wall. The economic performance of this design is examined and subsequently contrasted with one active design--the air collector/rock storage system. Architectural design criteria, solar performance characteristics, and the incremental solar cost of each design is briefly reviewed. Projections of conventional energy prices are discussed, along with the optimal sizing/feasibility criterion employed in the economic performance analysis. In addition, the effects of two incentive proposal--income tax credits and low interest loans--upon each design are examined. Results are reported on a state-by-state basis, with major conclusions summarized for each design. It is generally the case that incentives greatly enhance the economics of both system designs, although the contrast is greater for the passive design. Also, against the less expensive conventional fuels (natural gas and heating oil) the passive design was shown to offer a more cost effective alternative than the active system for most states.

1. INTRODUCTION

As the interest in passive solar energy heating applications grows, so does the need for consistent economic and technical analysis of alternative designs. In this paper we concentrate on one generic passive design, thermal storage walls, and contrast its performance with an air collector/rock storage system. One representative site from each state is chosen to measure the relative sensitivity of each solar design to changes in climate, cost factors, and regional variations in the price of conventional heating fuel alternatives. In the sections below we briefly discuss the components of our methodology which include design, performance, incremental costs, assumed energy futures, optimal sizing, and comparative financial analysis. For a more thorough discussion of detailed methodologies one should refer to the specific references listed throughout the paper. We conclude by summarizing the results and pointing out the key highlights of the analysis.

2. METHODOLOGY

We employ five basic steps in our evaluation of the economic performance of solar designs. First, architectural design parameters for a standard home and solar space heating system are established. Using these design parameters, physical performance of the individual systems in various locales is estimated using a computer simulation code based upon a solar load ratio (SLR) correlation [1,2]. The solar performance characteristics (e.g. glazing area and storage volume) obtained from the simulation model are combined with consistent estimates of unit incremental costs--collector independent (fixed) and dependent (variable) costs--to calculate costs of providing alternative quantities of heat (solar fraction) for each locale. Fourth, the costs of providing heat through conventional means (natural gas, heating oil, and electricity--both resistance and heat pumps) are projected for each locale in the analysis. And finally, the potential for solar installations is evaluated through our economic analysis which combines optimal system sizing, evaluation of proposed or potential legislative actions, and financial performance measured by several alternative criteria.

A standard home design of approximately 139.4m^2 (1500 ft^2) is being used throughout the analysis to allow interregional comparisons. Figure 1 contains a schematic for the Trombe wall design. Moreover, a 'tract' home concept and common building materials are assumed. This makes possible our examination for the potential of solar energy in residential space heating applications for a majority of new home buyers in the United States.

The modified solar-load ratio (SLR) correlation procedures developed by Los Alamos Scientific Laboratory [1,2] were utilized to estimate solar performance given the parameters of the above solar system designs. This procedure is capable of treating several design parameters as variables: i.e., nominal building heat loads, glazing type, number of glazings, glazing area, storage volume, and storage type. Regional variability in weather patterns are taken into account in the performance

* This work was supported by the Los Alamos Scientific Laboratory under contract to the US Department of Energy.

Fig. 1. Schematic for Trombe wall.

computations. The modified SLR performance correlations are used to determine the glazing (collector) area required to achieve given solar fractions for the specific solar design under analysis. The ratio of glazing (collector) area to storage volume was held constant for each of the solar systems to ease the computational burden and limit the almost infinite construction design possibilities.

Every effort was made to construct realistic cost estimates for each solar design. In all cases we isolate the add-on solar components so that they may be priced independent of traditional home costs. In the active system, solar add-on components included collectors, roof supports, insulated ducts, an air handling system (fans, dampers, and controls), and a rock storage bin. For the passive design the solar add-on components included the wall, glazing, and framing requirements [3,4]. Credit was given for a portion of a normal wall replaced by the south-facing thermal mass storage unit.

In many solar system concepts, there are two cost components: a fixed cost which is essentially independent of system sizes; and a variable cost associated with collector or glazing area requirements. However, no substantial fixed cost component was identified in the passive designs. This means that all costs associated with each passive system can be stated strictly in $\$/m^2$ ($$/ft^2$) of glazing area once a storage to glazing area ratio is fixed. A credit for the wall is included in the cost estimates. Costs for passive systems were developed by solar engineers and architects associated with the study [3,4]. Using Mean's 1978 construction cost indices, we subsequently adjust these materials and labor costs for each locale to account for regional variability in construction price indices and practices.

For the air collector/rock storage system, we separate the system into a fixed collector-independent component and a variable collector-dependent

component. The major portion of the rock storage bins, as well as the incremental insulated duct work and air handling system are treated as a fixed cost component -- i.e., their size and therefore installed dollar amount are assumed not to vary with changes in collector size [5,6,7]. The variable cost component included the collectors, support requirements, and the collector area dependent portion of rock storage. These incremental solar costs were developed after a careful survey of manufacturers, a preliminary look at the HUD, ERDA, and EPRI Solar Demonstration Programs, and detailed discussions with solar engineering consultants and installers.

Although we are examining many alternative energy futures, we utilize the proposed National Energy Plan (NEP) as modified by the recent natural gas compromise in Congress to construct projected fuel costs. A 1977 state-by-state energy data base for natural gas ($\$/m^3$ [$$/MCF$]), heating oil ($\$/m^3$ [$$/gal$]), and electricity ($\$/J$ [$$/Kwh$]) prices has been constructed previously [6,7,8]. We then develop future price projections at the wellhead for natural gas and oil, at the meter for electricity, and add in a transportation, distribution, and marketing cost adjustment component (natural gas and heating oil only) to arrive at delivered or metered cost. To construct equivalent delivered heating costs we transform the above fuel prices into a $\$/1.055 \cdot 10^9 J$ ($$/10^6 \text{ Btu}$) measure for each year. These figures are subsequently adjusted for furnace or heating equipment conversion efficiency.

We employ an equivalent set of criteria for our economic analysis of all solar energy system designs [3,5,6,7,8,9]. Reduced to its simplest form we evaluate a series of home heating systems that include a solar component, providing anywhere from 0 to 100 percent of the required heat, to determine the economically optimal mix of solar and conventional back-up systems. The net present value (NPV) of a solar addition in concert with the fuel cost from a conventional furnace over the heating system life is maximized. This is exactly equivalent to minimizing the cost of delivered heat to the home over a specified life time.

3. RESULTS

For the air collector/rock storage active system in only one state--Maine--does it prove economic to install solar when natural gas is the alternative fuel. The price of natural gas remains below the cost of solar through 1990, despite its (natural gas) rather rapid rate of increase under the recent compromise. Without the proposed NEP tax credits, there would be no states included in the feasible set.

If the Trombe wall without night insulation design is contrasted with natural gas, only in two states does it appear economic to install such a design in a new home: Maine in 1978 and Idaho in 1983. By the addition of night insulation to the Trombe wall concept some additional states join the feasibility set when natural gas is the alternative fuel (Map 1). Except for North Carolina, the additional states are located in New England.

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TO THE CHIEF OF STAFF, U.S. AIR FORCE, WASHINGTON, D.C.

**THE NATIONAL SECURITY INFORMATION
REPOSITORY, INFORMATION AND COMMUNICATIONS**

**Charles A. Feltman
Los Alamos National Laboratory**

**Stephen L. Carpenter
U.S. Department of Energy
Executive Secretary, Los Alamos National Laboratory
Division of Nuclear Materials**

Attachment

The National Security Information Repository is a new and innovative effort to gather, store and distribute classified information from the Los Alamos National Laboratory. It is a joint effort between the Laboratory, the Department of Energy, and the Defense Department.

The Repository will be located at the Los Alamos National Laboratory and will be managed by the Department of Energy. The Repository will be open to all government agencies and contractors who have access to classified information.

The Repository will be a central repository for classified information from the Los Alamos National Laboratory. It will be a secure facility that will be monitored and controlled by the Department of Energy.

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of systems for user applications and access to the information in the system. The system will provide:

1. A central repository for classified information from the Los Alamos National Laboratory.

2. A secure facility that will be monitored and controlled by the Department of Energy.

3. A central repository for classified information from the Los Alamos National Laboratory.

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16. A secure facility that will be monitored and controlled by the Department of Energy.

17. A central repository for classified information from the Los Alamos National Laboratory.

18. A secure facility that will be monitored and controlled by the Department of Energy.

The following is a copy of the letter sent to the
Chairman of the Board of Directors of the
National Association of Broadcasters by the
Secretary of the U.S. Department of Justice.
The letter discusses the proposed merger of
the National Association of Broadcasters and
the American Federation of Radio Broadcasters
and the potential antitrust problems involved
in such a merger. It also discusses the
possibility of a proposed merger between
the National Association of Broadcasters and
the American Federation of Radio Broadcasters
and the potential antitrust problems involved
in such a merger.

RE: NATIONAL ASSOCIATION OF BROADCASTERS
AND AMERICAN FEDERATION OF RADIO BROADCASTERS

The following is a copy of the letter sent to the
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the American Federation of Radio Broadcasters
and the potential antitrust problems involved
in such a merger.

process, the flow for the different grades of oil
is established in the rate plan, but it cannot be
understood to constitute a permanent standard plan for
all the oil wells. It will have clearly established the
method of calculating the rate for each well, the
method of calculating the production, the methods and
allowances for the supply requirements, etc., etc. All the
parts of this - although combined with and probably
more greatly for the calculation required by the
various parts will be established in writing on the
basis of which the oil companies can be
calculated.

Collaboration between the two organizations will be strengthened and will continue to be maintained through the joint publication of a journal.

1. The first step in the process of creating a new product is to identify a market need or opportunity.

Digitized by srujanika@gmail.com

~~2000 hours of flight for the month, or 100 hours
and complete 100 percent.~~

1.1.2. Experiments on the effect of the addition of

Classification of 11000 specimens will be done at the University of Illinois. The first report on collection characteristics for the first half of 1971 lists 112 items that are new to the herbarium. In addition, 10000 more items were collected, which were not included in the report of so much material sent from the State of California during preliminary herbarium surveys. This number of collections is about one-half of the total number of collections made by the University of Illinois herbarium between 1965 and 1971.

and because of the idea of the return from the past.
The first part of the book is concerned with the
idea of the past as it appears in the literature of
the period, and the second part with the idea of
the future. The third part is concerned with the
idea of the present, and the fourth part with the
idea of the self.

1. *Leucosia* *leucostoma* (Fabricius) (Fig. 1)

1. The first step in the process of creating a new product is to identify a market need or opportunity.

1. *Monachorum* 2. *Monachorum* 3. *Monachorum* 4. *Monachorum*
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85. *Monachorum* 86. *Monachorum* 87. *Monachorum* 88. *Monachorum*
89. *Monachorum* 90. *Monachorum* 91. *Monachorum* 92. *Monachorum*
93. *Monachorum* 94. *Monachorum* 95. *Monachorum* 96. *Monachorum*
97. *Monachorum* 98. *Monachorum* 99. *Monachorum* 100. *Monachorum*

On the other hand, the present study has been well received by the scientific community, which has provided the following references, and it has been widely cited in the media. These publications have also been apparently included in the following:

1. *Leucosia* *leucostoma* (Fabricius) (Fig. 1).
2. *Leucosia* *leucostoma* (Fabricius) var. *leucostoma* (Fabricius) (Fig. 2).
3. *Leucosia* *leucostoma* (Fabricius) var. *lutea* (Fabricius) (Fig. 3).
4. *Leucosia* *leucostoma* (Fabricius) var. *luteola* (Fabricius) (Fig. 4).
5. *Leucosia* *leucostoma* (Fabricius) var. *luteola* (Fabricius) var. *luteola* (Fabricius) (Fig. 5).

with the necessary experience to conduct negotiations for
international trade. The government has been
grateful to the World Bank and the World Health Organization
for their support in the development of our country.
In return, we have tried to do the same for them. We are
Proudly here to thank our partners, and we hope to
justify their confidence in our future development.
Actually, there still exists a long way before our country
would complete its development. We are determined to continue
to do our best to make our country a better place to live.
Thank you.

marketeers, they have not mainly regarded the
value of these contributions, but have concentrated
on the first piece of the story.

The last word on the subject of vegetation characteristics
will come in my next note, but I have some
interesting gathering's with New York in the last
cycle still here. Park City has no native trees, though
now the pines are quite common. The aspens
are the most abundant tree, and are found in
the lower elevations. The spruce is also
abundant, especially along the mountain streams. The
aspen is the most common tree in the upper elevations,
and is found in great abundance. The spruce is
also common, but is not so abundant as the aspen.
The pine is the most common tree in the upper elevations,
but is not so abundant as the aspen.

He was a man of great energy and determination, and he worked hard to build up his business and establish himself in the community.

the first time in the history of the world, the people of the United States have been called upon to decide whether they will submit to the law of force, or the law of the Constitution.

During the time of the Second World War, the British government established a secret service organization called MI-6. This organization was responsible for gathering intelligence information from agents who were secretly working for the British government. One of the most famous agents of MI-6 was a man named James Bond. James Bond was a skilled spy who was known for his ability to gather intelligence information from a variety of sources, including informants and other agents. He was also known for his ability to stay one step ahead of his enemies and to always come out on top. James Bond's success as a spy was due in part to his exceptional skills and knowledge, but it was also due to the fact that he was able to work with a team of highly skilled and experienced agents.

an economic return by trade - a condition of the performance guarantee of the project for the contractor's timely achievement of the target. Nature is working on a long-term basis, influencing differently the substrate than the short-term seasonal adjustment. The system will then be stabilized, because of the plastic, stabilized by a thin layer of high-strength aggregate. The concrete project is really to simulate the natural conditions of the soil, which will then stabilize on engineering the concrete through a series of different types of treatments.

the remaining group, the *low* metabolizers, have a much higher rate of metabolism. This is due to the fact that they have a greater number of cytochrome P-450 enzymes in their liver. The result is that they can process the drug more rapidly, which leads to a shorter half-life. This means that the drug will be removed from the body faster, resulting in lower concentrations of the drug in the blood over time. In contrast, the *high* metabolizers have fewer of these enzymes, so they process the drug more slowly, leading to a longer half-life and higher concentrations of the drug in the blood over time.

After the first year, the authorship of the book was given to the editor, and the editor's name was added to the title page.

A. G. WILSON / 17

• [Report a problem](#)

Based on the results of the experiments by K. and L. T. H. in 1957, the following differences between the two species of butterfly (*P. l. lantana* and *P. l. lantana*) can be summarized:

Identify and determine that will receive adequately at a reasonable rate. The following is intended to assist collectors thus. In the following we are not selective as to the type of material used in these maps, atlases, guides, and publications. They are presented to help the collector in his studies or investigations in which he wishes to illustrate the importance attached to certain problems or facts. Many of these publications are in the 1977 publications, but a few, such as the 1977 Guide to the National Parks, are not included.

From what ERV's can we learn about human evolution?

of the project. There are two ways and we know only recently selected. There is one of the methods a person can take now on the market further to make it work. The Illinois Institute of Technology has an excellent program for the study of the various methods of design, analysis, and synthesis of structures. It is a good place to go to study the physical and mechanical behavior of structures and obtain a good understanding of the various methods of analysis. I believe that in a year or two there will be involved much more knowledge and experience in these disciplines. The Illinois Institute has reported results from their research group in connection with the use of these techniques.

א. גָּמְנִיָּה :

The following is a list of the principal books and treatises, at present known, which have been written on the subject of the history of the American Revolution. The list is not complete, as many other works have been published since the time of the original compilation, and some of those mentioned have been republished or enlarged. The list is arranged in chronological order, according to the date of publication of the original work. The titles are given in full, and the names of the authors are given in full, except where they are well known. The list is not intended to be exhaustive, but it includes all the principal works on the subject.

10 of 10

1. Department of Civil Engineering, Faculty of Engineering,
Polar Polytechnic Institute, P.O. Box 10000,
Liman, Erzurum, Turkey (e-mail: ce@polar.edu.tr),
May 1999.
 2. Institute of Hydraulics and Hydrology, Department of
Hydrology and Water Resources, Institute of Hydrology
and Water Resources, P.O. Box 10000, Ankara, Turkey
(e-mail: ahmet.yilmaz@ihm.gov.tr),
May 1999.

APPENDIX B. BY-LAWS OF THE INTERNATIONAL SOLAR ENERGY SOCIETY, INC.

774 Geographical and Economic Survey of India 1909 भू-भाष्यक पृष्ठा

TABLE I

DISTRIBUTION OF H & C AND ALIPHATIC COMPOUNDS IN COLLECTOR TUBE AND TEMPERATURE RANGE

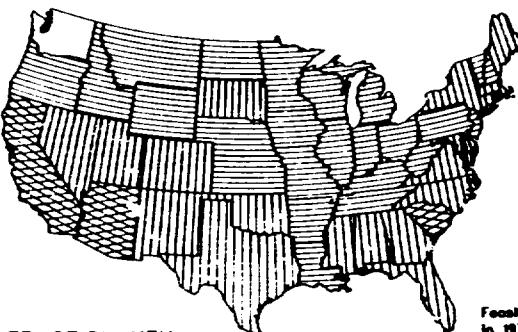
Collector Type	Non-Concentrating		Concentrating	
Temperature Range	Liquid-Heaters	Air-Heaters		
low temperature $T < 120^{\circ}\text{F}$	H1 heat pump C1 heat pump/solar	H1 heat pump C1 heat pump/solar		
medium temperature $120^{\circ}\text{F} < T < 230^{\circ}\text{F}$	W1 water heating H4 space heating H5 shelter heating D1 drying W1 process hot water C2 space cooling C3 space cooling S1 process steam CA active cooling	W2 water heating H2 space heating H3 shelter heating DA drying WA process hot water C2 space cooling C3 space cooling CA active cooling		
high temperature $T > 230^{\circ}\text{F}$			C1 space cooling CA active cooling W1, WA process hot water S1 process steam	

TABLE 2

FY-1974

Map 7

SOLAR FEASIBILITY FOR TROMBE WALL W/O NIGHT INSULATION
ALTERNATIVE FUEL - ELECTRICITY (RESISTANCE)
NO INCENTIVES
(30-YEAR LIFE CYCLE COST BASIS)



SOLAR FRACTION KEY



.10-.25



.30-.40



.45-.55



.60+

Feasibility achieved
in 1978 for all states
except WA.