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This study is based on the computer simulation model of a solar heated broiler house in four locations in Arkansas. This simulation model estimated the annual energy savings in each broiler house due to the installation of a solar heating system. This paper uses present value analysis to estimate the life cycle costs of heating conventional and solar heated broiler houses in the state of Arkansas. From these calculations, the number of years required to achieve a break-even cost of heating is estimated.

1. INTRODUCTION

The post World War II years have witnessed a tremendous increase in the importance of the Arkansas broiler industry. In 1945, approximately 17 million broilers were grown in Arkansas. In the 1970's this figure has expanded to well over 500 million birds. (1) This trend is significant on both the national and state levels. Arkansas is currently the leading broiler producing state in the nation. In addition, the broiler industry accounts for over seventeen percent of the total value of agricultural production in Arkansas, ranking second only to soybean production.

While the Arkansas broiler industry has enjoyed three decades of expansion, the recent developments in the energy sector have placed this industry in a precarious position. It has been estimated that 17.9 million gallons of liquified petroleum gas (LPG) and 492 million cubic feet of natural gas were consumed by Arkansas broiler growers in 1974. (2) These quantities of fuel which are required for space heating purposes in broiler houses account for the fact that Arkansas is the leading state in per capita consumption of LPG.

The objective of this study is to determine the economic conditions under which a solar heated broiler house may achieve an accumulated cost of operation which is less than the accumulated cost of conventional heating. In particular, the number of years required to achieve this break-even cost was determined.

2. SIMULATION MODEL

This report is based on the simulated thermal performance of a solar heated broiler house at four locations in Arkansas: Fayetteville, Fort Smith, Little Rock, and Texarkana. The simulation model performed hourly calculations of energy requirements for heating the broiler house as well as hourly calculations of energy requirements for heating the broiler house as well as hourly estimates of available solar radiation on the surface of the collector. The hour by hour calculations were based on meteorological observations available from the National Climatic Center in Asheville, North Carolina. A summary of parameter values included in the simulation model is given in Table 1.

Table 1

Parameter Specification in Simulation Model

<u>Broiler House Characteristics</u>	
Dimensions	40' x 300'
Wall Height	8'
Roof Slope	4' rise per 12' run
End Door (2) Dimensions. . .	1 1/4" urethane insulation with an estimated R value of 8 per inch thickness of insulation. This insulation covers the inside of all doors, walls and roof area.
<u>Solar Heating System Characteristics</u>	
Collector Area	1,000 ft^2
Storage Volume	2,270 ft^3
Storage Dimensions	Diameter = 16.2' Height = 11'
Storage Material	Crushed limestone
<u>Flock Characteristics</u>	
Flock Size	15,000 broilers
Dates of Growth.	January 1 - February 21 March 15 - May 5 May 27 - July 17 August 8 - September 28 October 20 - December 10

The broiler house and solar heater characteristics in the simulation model are patterned after an experimental solar heated broiler house which is now in operation at the University of Arkansas Agricultural Experiment Station in Fayetteville.

The simulation model yielded estimates of the energy required for space heating purposes to grow each flock of broilers. The estimates of the average annual heat load are given in Table 2. This table shows the total heat load required to heat the building be a conventional system as well as the average annual heat load to be provided by a supplemental fuel with a solar heating unit. These results were based on a collector size of 1,000 ft^2.

3. Present Value Model

The accumulated net present value cost of heating was calculated to determine the number of years required for a solar heated broiler house to achieve an accumulated present value heating cost less than the cost of a conventional heating system. The present value method of comparing heating costs was necessary in order to account for the timing of the different costs.

In general, where Q_t is the sum of money spent in t periods, and the interest rate is i, then its present value, PV, is given by:

$$PV = \frac{Q_t}{(1 + i)^t}$$

The above formula makes it possible to find the present value of the annual cost of heating during each year of the operation of the competing heating systems.(3)

Table 2

SIMULATED AVERAGE ANNUAL BROILER HOUSE HEAT LOADS FOR FOUR ARKANSAS LOCATIONS

	Average Annual Heat Load (10^6 BTUs)	Average Annual Energy Savings (10^6 BTUs)	Average Annual % Supplied by Solar
Fayetteville			
Total Heat Load	346		
Solar	181	165	48 %
Fort Smith			
Total Heat Load	276		
Solar	133	143	51 %
Little Rock			
Total Heat Load	234		
Solar	113	121	52 %
Texarkana			
Total Heat Load	181		
Solar	67	114	63

In order to find the accumulated present value of the future costs of heating the following formula was used:

$$PV = \frac{Q_1}{(1+i)} + \frac{Q_2}{(1+i)^2} + \frac{Q_3}{(1+i)^3} + \ldots + \frac{Q_n}{(1+i)^n} = \sum_{t=1}^{n} \frac{Q_t}{(1+i)^t}$$

This formula calculated the accumulated present value cost of heating for each year in the assumed twenty year management period of the broiler enterprise. Heating costs which were included in the analysis were: acquisition costs, energy costs, maintenance and insurance. Property taxes were assumed to be zero. In addition, the effect of income tax reductions due to annual heating costs were included in the analysis.

The study considered values for initial investment from $5,000 to $18,000. This corresponded to a price range of five to eighteen dollars per square foot of collector area. In addition it was assumed that these values for initial investment included all relevant costs covering initial installation of the solar units.

Annual energy costs of the competing heating systems were dependent on the quantities of LPG which were consumed in the conventional system or as a backup source of heat in the solar system. An initial price of forty cents per gallon of LPG was assumed. Annual inflation rates ranging from zero to sixteen percent were used to determine the price of fuel in a particular year of the present value model.

Although it is recognized that annual maintenance costs are dispersed at irregular intervals throughout the heating system's life, the lack of adequate records prevents an exact determination of maintenance costs. In their absence, annual maintenance costs were stated as a percentage of initial investment. The basic present value model assumed that annual maintenance cost was equal to one percent of the initial investment.

Information concerning insurance rates on solar equipment is subject to uncertainties similar to those for maintenance costs. The present value calculations in this study assumed an insurance rate of $9.10 per thousand dollars of insured value. This rate was obtained from insurance companies in the Fayetteville area as being the approximate rate which would apply to solar equipment in broiler houses.

The present value model estimated the number of years required before a solar heated broiler house could achieve a break-even cost of heating, relative to a conventional heating system. The sensitivity of the break-even year to changes in the economic variables was determined. Thus it was possible, for example, to determine the effect of a reduction of the acquisition cost of the solar equipment on the occurrence of the break-even year of operation. Likewise, the effect of alternative assumed rates of fuel inflation, discount rates and maintenance costs were estimated on the break-even period.

4. RESULTS

Figure 1 shows the areas of the state of Arkansas where solar heating costs reach a break-even cost with conventional systems within the twenty year management period. Of the four locations, Fayetteville enjoys the greatest regional advantage for the introduction of solar energy, followed by Fort Smith, Little Rock and Texarkana, in declining order. For example, at an assumed average inflation rate of ten percent the Fayetteville solar heating unit was estimated to achieve a break-even cost of heating in nine years. This is compared to twelve years in Fort Smith; sixteen years in Little Rock; and seventeen years in Texarkana. The major factors accounting for these regional variations is the difference in the annual amount of fuel saved by the solar unit.

Figure 2 presents the occurrence of break-even years for the simulated Fayetteville solar unit. It assumes the operation of a 1,000 square foot collector system at investment levels ranging from $6,000 to $18,000. This investment represents all costs associated with the initial installation of the system. According to these calculations, the shortest break-even period which could result would be a two year period at an investment of $6,000 and a minimum average annual rate of fuel inflation of ten percent. At this rate of inflation an increase in initial investment to $8,000 would cause the break-even period to jump to nine years. A $10,000 investment would result in a fourteen year break-even period. A $12,000 investment at the same fuel inflation rate of ten percent would require an estimated eighteen year period to elapse before the break-even cost of heating could be achieved.

The break-even periods associated with alternative levels of initial investment for the simulated Fort Smith solar heating system are presented in Figure 3. The initial observation which can be made is the fact that the estimated break-even periods in Fort Smith are longer than those in Fayetteville. The shortest break-even period which was estimated to occut (in the investment range of $6,000 - $18,000) was four years at an assumed investment of $6,000 and an average annual fuel inflation rate of 16 percent. To achieve a break-even cost of operation within the twenty year management period, a minimum rate of fuel inflation of three percent would be required. However, this rate would not allow a break-even cost to occur until the twentieth year of operation.

Figures 4 and 5 present similar illustrations of the break-even periods of use of simulated solar units in Little Rock and Texarkana. The break-even periods illustrated in these figures reflect the reduced levels of fuel savings achieved at these locations. It should be noted that the maximum investment which can be made in either location, while allowing a break-even cost to be achieved within the management horizon is an estimated $14,000. An investment of this magnitude would not allow a break-even cost of heating to be achieved for eighteen to nineteen years for the range of assumed fuel inflation rates. The minimum break-even period which was estimated for an investment of $6,000 and a fuel inflation rate of sixteen percent was seven years for both the Little Rock and Texarkana systems.

Figure 6 illustrates the impact on the occurrence of the break-even year of operation due to alternative levels of the discount rate. Discount rates of five to ten percent were examined. The break-even cost of heating was calculated for each of these discount rates at an assumed initial investment of $10,000 in Fayetteville. The curves portrayed in Figure 6 illustrate the break-even years at each rate of assumed fuel inflation. For example, at an inflation rate of ten percent, the break-even period was estimated to be ten years at a five percent discount rate. At this assumed inflation rate of ten percent, an increase in the discount rate of one percent results in an estimated increase in the break-even period of one year. This tradeoff held true for all discount rates which were considered, at a ten percent rate of inflation. However, at lower rates of inflation changes in the discount rate had a slightly greater impact on the occurrence of the break-even year. For example at an inflation rate of six percent a discount rate of five percent would result in a break-even cost of heating in fourteen years. At this point, an increase of one percent in this discount rate resulted in an increase of two years in the estimated break-even cost of heating. The increased responsiveness of the break-even year to changes in the discount rate at low rates of fuel inflation occurs because interest expenses constitute a greater proportion of total heating costs at low fuel inflation rates than at higher rates of inflation.

One of the categories of solar heating costs which is subject to a great deal of uncertainty is that of expected annual maintenance costs. Part of this uncertainty stems from the inadequate data base pertaining to expected future maintenance of solar equipment. In addition there exists a wide variety of equipment warranties, depending on the type of equipment and manufacturer policy. (4)

The effect of three alternative assumptions concerning the magnitude of maintenance expenses on the break-even period of operation is shown in Figure 7. Annual maintenance costs were assumed to be either zero, one percent or two percent of total initial investment. The result of a change in assumed maintenance cost can be easily recognized. If expected annual maintenance costs are assumed to be zero and the rate of fuel inflation is ten percent, then the break-even year will occur after thirteen years of operation. With this set of assumptions it appears that an increase in expected annual maintenance costs of one percent of initial investment will add one year to the break-even period. For example, an increase in annual maintenance expense from zero to one percent of investment increases the break-even period to fourteen years. An additional increase in annual maintenance cost to two percent results in a fifteen year break-even period. It should be emphasized that these estimates are based on an assumed initial investment of $10,000.

Figure 8 illustrates the impact of tax deductible expenses on the break-even period. At an investment level of $10,000 and a tax rate of zero, the break-even period was increased by an estimated five years over a project which utilized an income tax rate twenty five percent. For example, at an inflation rate of twelve percent the break-even year for the project with no tax deductions was seventeen years. This may be compared to a twelve year break-even period where tax deductible were taken advantage of.

5. SUMMARY AND CONCLUSION

In summary, this paper utilized a present value model to determine the number of years required to achieve a break-even cost of heating with a solar broiler house heating system. These break-even periods were calculated for four locations in Arkansas. Economic variables which were included in the analysis were initial investment level, fuel inflation rate, discount rate, insurance expense and annual maintenance cost. The analysis showed that the Fayetteville location enjoys a regional advantage over the other locations which were studied.

It should be pointed out that this study did not attempt to estimate the economic impact of the introduction of solar heating on the financial stability of the broiler enterprise. The years of operation of the solar unit prior to the break-even year may place an adverse strain on the finances of the enterprise. Because of this possibility, it may not be feasible to advocate the introduction of solar heating in the broiler industry despite the fact that a reduction in life cycle heating costs will be achieved.

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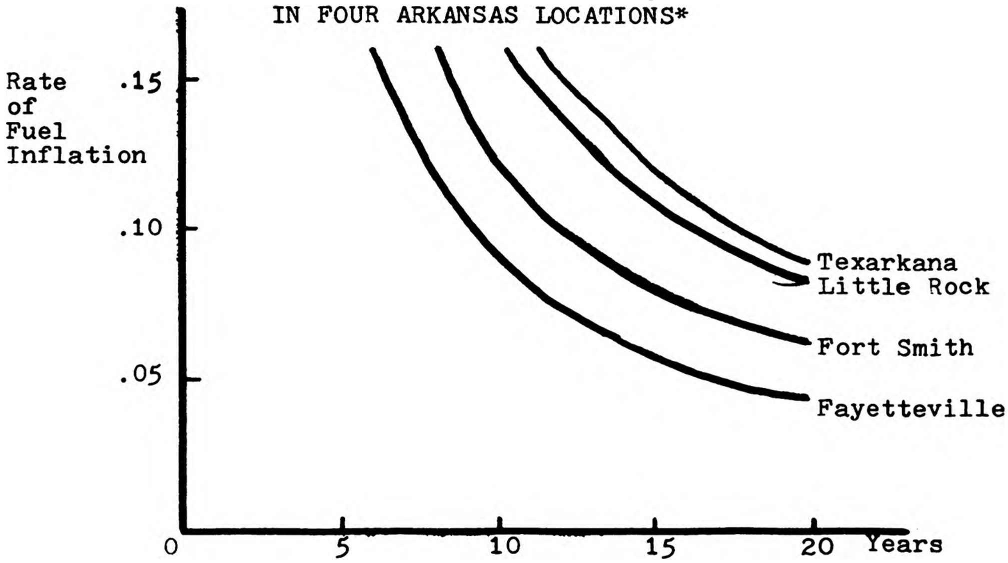
BIOGRAPHY

Dr. Gunderson received his Ph.D. from the University of Arkansas and is now a member of the department of economics at Southeast Missouri State University. Dr. Redfern, a Ph.D. graduate of Oklagoma State University, is in the department of agricultural economics and rural sociology at the University of Arkansas.

FIGURE 1

RELATIVE BREAK-EVEN PERIODS
IN FOUR ARKANSAS LOCATIONS*



*Assumes an initial investment of $8,000 per 1,000 ft^2 collector area.

FIGURE 2

FAYETTEVILLE BREAK-EVEN PERIODS
AT ALTERNATIVE INVESTMENT LEVELS

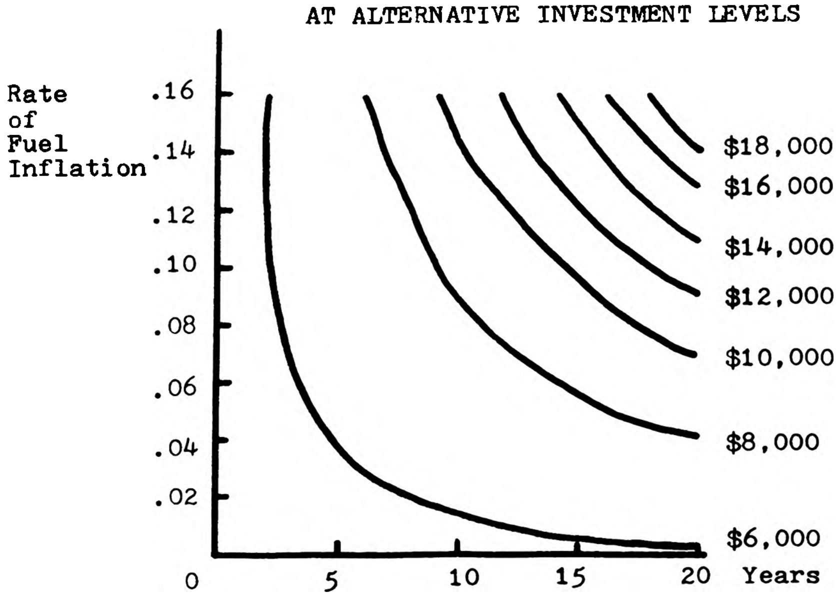


FIGURE 3

FORT SMITH BREAK-EVEN PERIODS
AT ALTERNATIVE INVESTMENT LEVELS

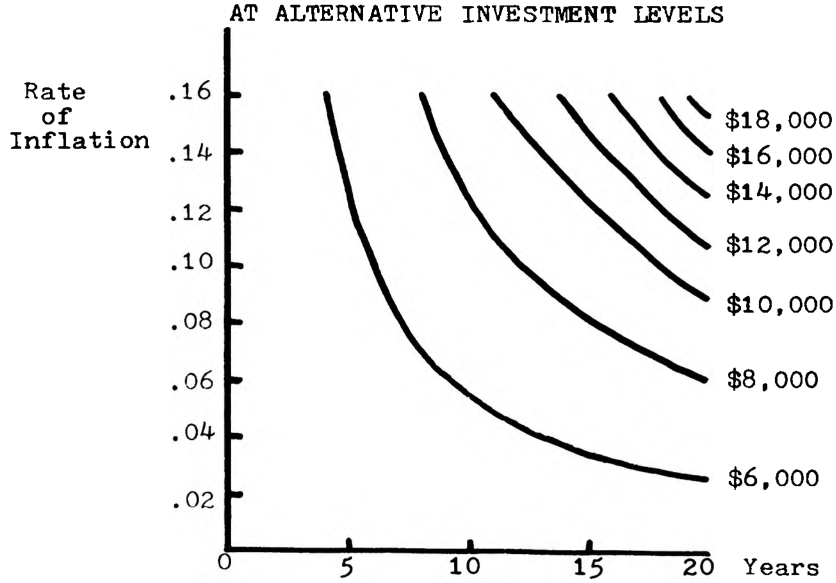


FIGURE 4

LITTLE ROCK BREAK-EVEN PERIODS
AT ALTERNATIVE INVESTMENT LEVELS

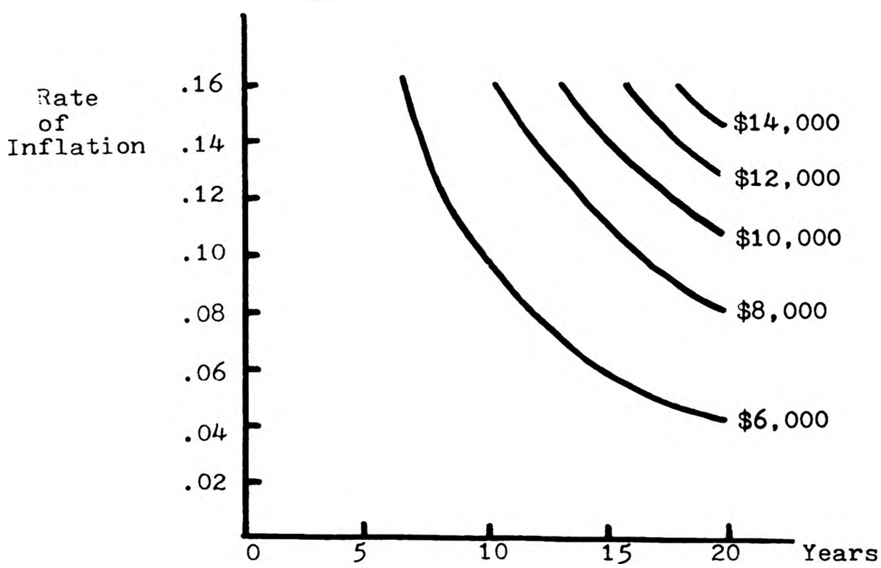


FIGURE 5

TEXARKANA BREAK-EVEN PERIODS AT ALTERNATIVE INVESTMENT LEVELS

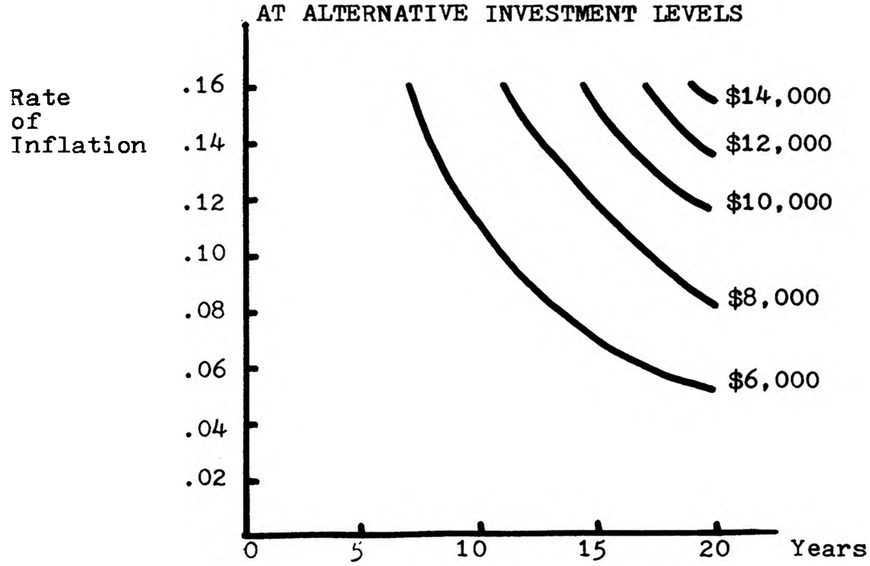
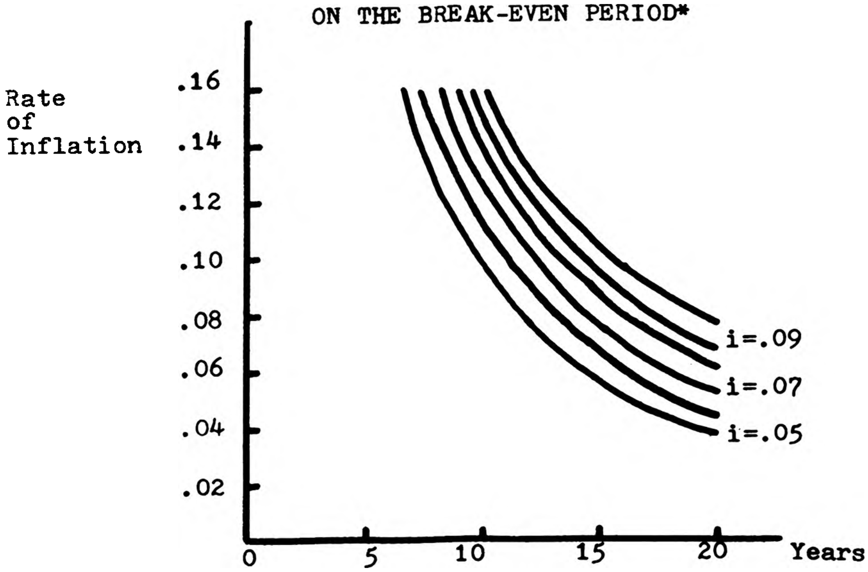


FIGURE 6

THE EFFECT OF ALTERNATIVE RATES OF DISCOUNT ON THE BREAK-EVEN PERIOD*



*Assumes an investment of $10,000 for a 1,000 ft^2 collector in Fayetteville

FIGURE 7

THE EFFECT OF ANNUAL MAINTENANCE COST ON THE BREAK-EVEN PERIOD

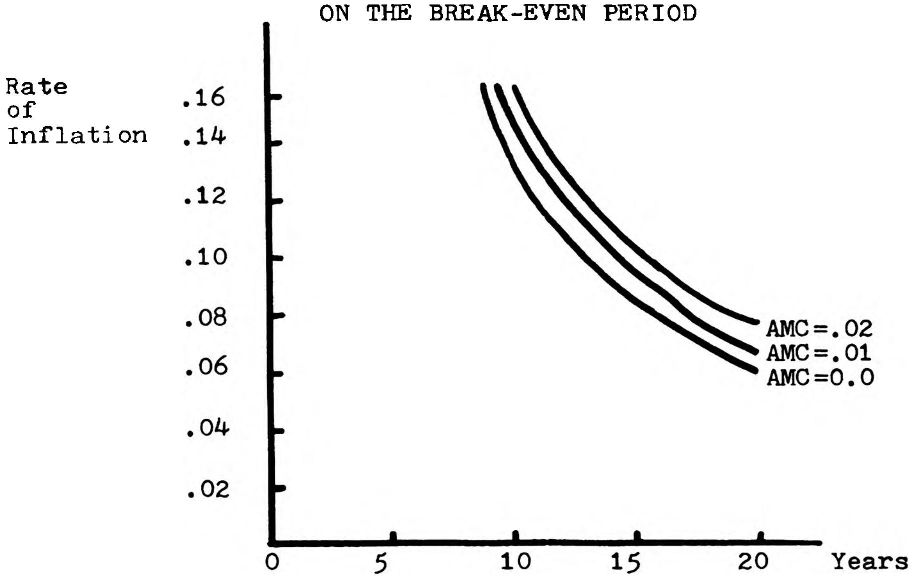
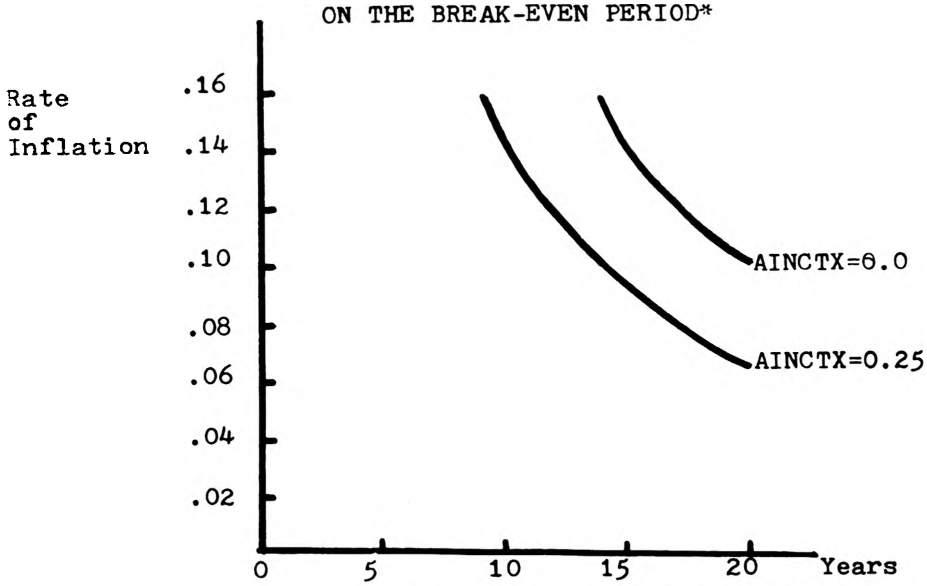


FIGURE 8

THE EFFECT OF INCOME TAX REDUCTIONS ON THE BREAK-EVEN PERIOD*



*Assumes an investment of $10,000 for a 1,000 ft^2 collector in Fayetteville

AINCTX = marginal income tax rate