NBSIR 76-1127

Evaluating Incentives for Solar Heating

Rosalie T. Ruegg

Building Economics Section
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Final Report

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U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, ***Secretary***
Edward O. Vetter, *Under Secretary*
Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Acting Director***

PREFACE

This study was initiated by a request from the National Conference of State Legislatures (NCSL) for information on the cost effectiveness of incentive policies for solar energy to be given at an NCSL training seminar. The presentation, entitled "The Impact on Owner Costs of Alternative Incentive Policies for Solar Heating," was given March 26, 1976 at the NCSL Seminar on Renewable Solar Energy in Denver, Colorado.

In response to resulting widespread interest voiced by state and federal policy analysts and decision makers, the Building Economics Section in the Center for Building Technology, Institute for Applied Technology, National Bureau of Standards, has prepared this summary report of the research methodology, the case examples, and the conclusions. It is intended as a guide to assist analysts and policy makers in the economic evaluation of alternative policies for encouraging the use of solar energy systems in buildings. The purpose is to promote the formulation of economically effective incentive policies.

Appreciation is extended to the members of the CBT staff who reviewed the report, and to participants in the NCSL Solar Energy Seminar who offered useful comments on the presentation. Special appreciation is extended to Dr. Harold E. Marshall, Chief of the Building Economics Section, for his valuable assistance throughout preparation of the report.

ABSTRACT

This report provides a life-cycle cost model and a computer program for measuring the dollar impacts of alternative incentives on the private costs of a solar heating system. In addition, it applies the evaluation model in six case examples, for seven selected incentives.

The purpose of the report is to assist state and federal legislators in formulating effective policies for encouraging the widespread use of solar energy systems in buildings. It does this by promoting quantitative assessment of the kinds of incentive programs now being considered for adoption by many state legislatures and by the U.S. Congress.

The results of the case examples indicate that the effectiveness of a given incentive program will differ by region, by type of building, and by fuel prices; that in some states the incentive programs now being enacted will not be worth their administrative costs; and that an indepth assessment of policy implications should be made of the differential impact of incentive programs on residential versus commercial use of solar energy.

EXECUTIVE SUMMARY

At least 12 state legislatures have already passed bills that provide direct financial incentives for the purchase of solar energy systems. These incentive policies include property tax exemptions, tax credits, direct grants, sales tax exemptions, and income tax deductions. A number of other states are in various stages of formulating and enacting similar programs, and several incentive bills are now pending in the U.S. Congress.

In order to formulate effective solar policy, legislators now in the process of developing incentive programs will require an evaluation of the comparative impacts of these programs. Those states that have already enacted incentive legislation will require an evaluation of its effectiveness in order to determine the need for modification or further legislative action.

The primary purpose of this report is to provide and illustrate a method for measuring and comparing the impacts of alternative incentive policies. A further purpose is to analyze the results of case examples for general conclusions pertinent to the development of effective incentive policies.

First, a life-cycle cost model for measuring costs to the purchaser of a solar heating system is presented. The model is designed to measure private ownership costs both before and after the imposition of seven selected types of incentives, i.e., a direct grant, an income tax credit, a reduction in the property tax, a reduction in the sales tax, a depreciation tax writeoff, an interest rate subsidy, and a special tax on fuel.

Second, a computer program to facilitate implementation of the life-cycle cost model is described and listed. Third, the method is demonstrated in six case studies. Four deal with representative residences in climate regions typical of Madison, Wisconsin and Albuquerque, New Mexico, and are based on conventional energy costs of 45¢ and 90¢ per therm of heat supplied (equivalent to \$.015/KWH and \$.03/KWH of electricity respectively). The other two case studies are for a commercial building in a climate region typical of Madison, Wisconsin, using a conventional energy cost of 45¢/therm in one case, and 90¢/therm in the second case. All of the case studies are based on a specified set of assumptions regarding solar energy system costs, performance, and durability; fuel prices; heating loads; and tax and interest rates. These assumptions reflect estimated values; there are considerable uncertainties as to what are appropriate values to assign to certain of the key parameters, particularly system durability and maintenance costs.

Lastly, a brief summary is provided, conclusions are drawn based on the case studies, and recommendations are made for further research.

The evaluation method consists of using a life-cycle cost model to determine the annual net savings (or net losses) to the owner of a solar heating system used in a building over a given period. The calculation of annual net savings takes into account the costs of purchasing, installing, maintaining, repairing, and insuring the system; the cost savings from reducing the consumption of conventional energy; the combined cost effects of property taxes, sales taxes, and income tax deductions; and the modifying cost effects of the seven selected incentive policies. All cash flows are discounted to a uniform annual cost basis and are adjusted to exclude the effects of inflation.

The computer program is written in BASIC language. It is formulated to allow the analyst flexibility in specifying the values of key parameters.

In the residential case study that assumes a climate like Madison, Wisconsin, it is found that incentives are required to make the solar energy system cost effective if conventional energy is available at an initial price of 45¢/therm (i.e., about 38¢/gal for #2 fuel oil or 1.5¢/kwh of electricity). However, with a doubling of the cost of conventional energy to 90¢/therm (about 76¢/gal or 3¢/kwh) the solar energy system appears decidedly cost effective without special incentives. Comparing the impacts of (1) a grant (or a tax credit) of $1000, (2) exemption from the assumed 3 percent effective property tax, (3) a depreciation writeoff against both state and federal taxable income over five years, (4) exemption from the assumed 4 percent sales tax, (5) an interest subsidy on the mortgage loan of 2 percent, and (6) a special tax of 20 percent on fuel, it is found that the property tax exemption and the 5 year depreciation have the largest impacts on owner costs, given the stated assumptions. However, it is found that for this case none of the incentives applied alone would be sufficient to make the solar system cost effective if the cost of conventional energy were 45¢/therm. The exemption from the 4 percent sales tax and the provision of an interest subsidy of 2 percent appear particularly ineffective.

For the residential case study that assumes a climate like that of Albuquerque, New Mexico, the solar energy system is found to be slightly less favorable from a cost standpoint than in the Madison case study.[1] This reflects the fact that the decline in the performance of the solar energy system from 75 percent of the heating load in Albuquerque, to 47 percent in Madison, is more than compensated for by the larger heating

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[1] For convenience, the case studies are hereafter referred to as the Madison and Albuquerque case studies, although the values of parameters other than climate are not necessarily specific for Madison and Albuquerque.

load in Madison relative to Albuquerque. The net effect is that more Btu's are supplied by the solar energy system in Madison than in Albuquerque.

In the commercial case studies, the solar energy system appears substantially less attractive economically than in the counterpart residential application (based on buildings of equal size with similar heating loads). This difference reflects (1) the assumption that the "opportunity cost of capital" is substantially greater for business investments than for homeowner investments, and (2) the impact of current tax laws, which allow tax deductions for fuel costs (as for other business expenses), thereby reducing the effective fuel savings from solar energy systems used in commercial buildings.

The following conclusions are based on the application of the evaluation method to the several case studies:

(1) In some states, the incentive policies now being enacted will probably not be worth the administrative costs required to implement them.

(2) The effectiveness of a given incentive policy will differ by region, by type of building, and by fuel prices.

(3) For buildings of equal size and heating load, it appears that more incentive is required to make a solar energy system cost effective for use on a commercial building than on an owner-occupied residence.

(4) To determine an economically effective incentive policy, it is necessary to assess and compare system costs to owners with and without alternative incentive policies.

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1. INTRODUCTION

1.1 Background

In face of the energy crisis, many states, as well as the federal government, are considering the adoption of programs which will (a) eliminate any existing fiscal impediments to, and/or (b) provide positive economic incentives for the widespread use of solar energy systems in the space conditioning of buildings. Twelve state legislatures have already passed bills that provide various kinds of direct financial incentives for the purchase of solar energy systems, such as property tax exemptions, tax credits, sales tax exemptions, and capital depreciation allowances. Twelve more states have established other special programs to encourage use of solar energy systems, such as research and development programs and life-cycle costing requirements for construction of state facilities.[1] A number of other states and the federal government are currently at various stages in the process of formulating and enacting similar programs.[2] In attempting to decide the need for and the relative merits of alternative incentive policies, there have been discussions both of the existing biases against use of solar energy and of the probable nature and direction of effects of

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[1] National Conference of State Legislatures Energy Task Force, Turning Towards the Sun, Vol. 1 (Abstracts of State Legislative Enactments of 1974 and 1975 Regarding Solar Energy), undated; and Robert M. Eisenhard, A Survey of State Legislation Relating to Solar Energy, National Bureau of Standards Interagency Report, 76-1082, April 1976.

[2] J. Glen Moore, "Solar Energy Legislation in the 94th Congress: A Compilation of Bills through June 30, 1976," the Library of Congress, Congressional Research Service, Unpublished Abstracts of Bills.

various policies.[1] However, the evaluation of fiscal policies has, for the most part, been cursory in nature; quantitative assessment of the cost impacts of specific programs imposed under particular circumstances appears generally lacking.[2] Thus there is a substantial gap in the information that is necessary to formulate state and federal incentive programs which will have the desired impact of encouraging building owners to purchase solar energy equipment.

1.2 Purpose, Scope, and Organization

The purposes of this report are (1) to provide a model for measuring the dollar impacts of various incentive policies on the cost of owning a solar energy system and (2) to calculate in case studies for buildings constructed in two regions of the United States, the cost impacts of selected incentives under assumed conditions.[3]

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[1] See, for example, Richard Robbins, "Fiscal Impediments and Inducements," Proceedings of the Workshop on Solar Energy and the Law Ed. William A. Thomas, National Science Foundation RA-575-004, March 1975, pp. 11-15.

[2] An existing quantitative study of incentives (Craig H. Peterson, The Impact of Tax Incentives and Auxilliary Fuel Prices on the Utilization Rate of Solar Energy Space Conditioning, National Science Foundation RANN Grant No. AER-09043-A01 and APR 75-18004, January 1976) takes a macro approach; i.e., it analyzes incentive policies from the standpoint of forecasting impacts on future utilization rates nationwide. In contrast, this study provides a micro approach for analyzing the impact of alternative policies at the individual, regional or state level.

[3] This represents an advance over a previous work by the author, in which the focus was on setting forth the basic method of evaluating overall system costs and the economic conditions for making cost-effective tradeoffs in solar system/building design (Rosalie T. Ruegg, Solar Heating and Cooling in Buildings: Methods of Economic Evaluation, National Bureau of Standards IR 75-712, July 1975). While taxes and incentives were discussed in the earlier report, the model lacked the detail required for the in-depth analysis of a variety of incentive policies. This report expands the life-cycle cost model of the earlier report to the required level of detail, develops a computer program to exercise the more detailed model, and applies the program to selected case studies.

The scope of the study is defined as the private cost impacts of government incentives. That is, the evaluations are confined to the dollar impact on direct costs to the owner; possible benefits or costs external to the direct owner, such as reduced environmental pollution, balance-of-payments effects, national defense considerations, and the value of conserving fossil fuels for future generations, are not included in this evaluation. The focus is on private costs because they are the prime determinant factor in the adoption or rejection of solar energy systems for heating and/or cooling residences and commercial buildings. The private decision maker who is free of government control probably will not take into account all the external social costs and benefits that would result from solar applications.

At the same time, the importance of external net benefits should be recognized. They in fact provide the economic efficiency rationale for publicly-provided incentives to encourage private use of solar energy systems. The decision of states or the federal government to provide incentives implies the existence of important external net benefits from solar energy utilization.

Thus, there are two main economic issues regarding incentives: (1) Are public incentives justified on economic efficiency grounds? (2) If incentives are to be provided, which incentive policy is preferable and how must it be designed to achieve the desired effect? Despite some attempts to evaluate social net benefits from solar energy, this first issue is likely to be decided in the political realm. This is not surprising given the difficulty of developing reliable measures of social benefits and costs. In any case, the current level of activity in state and federal legislatures would indicate that the question is already being answered in the affirmative in many areas. For these reasons, the focus here is on the second of the two main issues, i.e., what is the preferred choice and design of alternative incentive policies.

This issue is treated here only by an evaluation of comparative cost impacts; hence, it is treated in a limited perspective. There are many other criteria against which a fiscal policy could be evaluated, such as the ease and economy with which it can be administered, its relative impact on different income groups (i.e., equity effects), and the ease of disengagement of the state from the policy once its usefulness is deemed past.[1] However, the cost impact is the most critical criterion, because a policy without the impact necessary to make solar energy systems cost effective will fail the "raison d'être" of the incentive policy.

Figure 1 depicts the sequence of questions regarding the two economic issues and the key factors upon which they each rest when a broader, more comprehensive set of criteria are considered. In summary, the first question shown, "Are Incentives Justified?" rests on the existence of social net benefits beyond the direct private benefits. The next two questions shown, "Are Incentives Necessary for Widespread Use?" and "How Much?" depend upon the competitive economic position of solar

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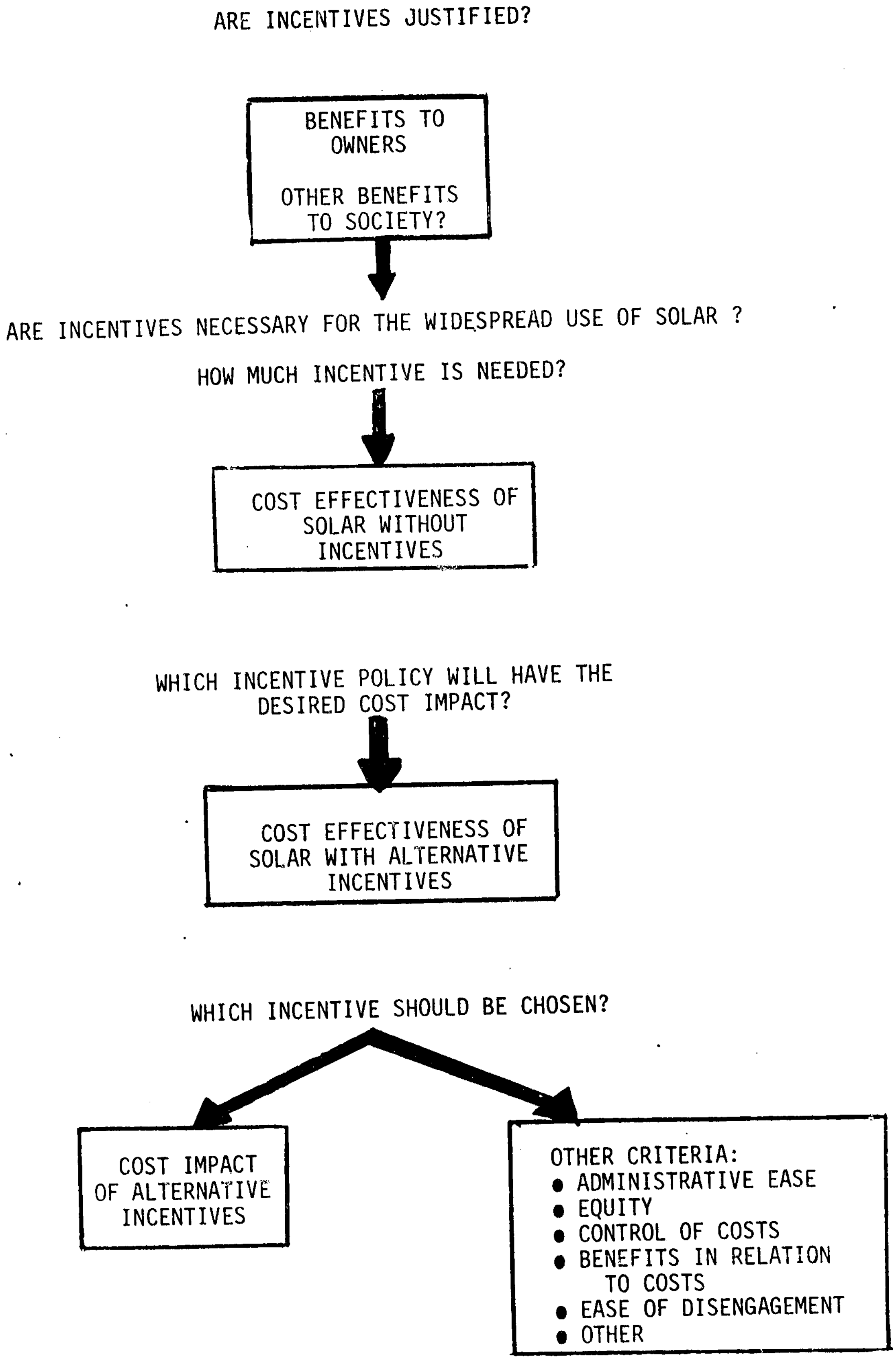
[1] Anthony Downs, for example, in his book on housing subsidies, lists 18 criteria against which a subsidy policy should be evaluated. [Anthony Downs, Federal Housing Subsidies: How Are They Working? (Lexington, Massachusetts: Lexington Books, 1973), pp. 30-31.]

Figure 1

Questions on Incentives



energy systems without incentives.[2] An inspection of existing costs may reveal that incentives are not needed due to an already existing "natural" profit incentive. On the other hand, it may be found that the incentive required to bring about widespread use is too large for the governmental units' budget to support. The fourth question, "Which Incentive Policy will have the Desired Cost Impact?" can be answered by evaluating owner costs after alternative incentives have been imposed and comparing net impacts. The fifth question, "Which Incentive Should be Chosen?" is a reminder that there are considerations other than the impact on owner costs which shoud be taken into account in the final selection of an incentive policy.

The paper is organized in five sections. Following the Introduction, Section 2 lists and describes briefly seven incentive policies which the model is designed to treat and which are evaluated in the case studies. Section 2 also gives a brief overview of recent state and federal legislative activity that pertains to incentive policies for solar energy systems.

Section 3 first presents the life-cycle cost model for evaluating costs to homeowners and commercial building owners before and after one or more of the seven incentives is imposed. Section 3 then describes and lists a computer program which is provided to exercise the life-cycle cost model.

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[2] Theoretically, if incentives are "justified" by social externalities, then they are "needed" to obtain optional usage of solar energy systems. This is a different issue than the question as to whether incentives are needed for widespread use. With respect to the question of the amount of incentive required to encourage widespread use of solar energy systems, the simplifying assumption is made that if they are made cost effective they will be widely adopted. This assumption may not be valid. If demand is very inelastic with respect to price, then price incentives will not have a large impact even if they are theoretically justified.

Section 4 contains six case studies in which the life-cycle cost model developed in Section 3 is applied to measure the dollar impact of selected values of the seven types of incentive policies under assumed conditions for a building constructed in two regions of the United States. Two case studies are for an owner-occupied residence in Madison, Wisconsin; two are for an owner-occupied residence in Albuquerque, New Mexico; and two are for a commercially-owned building in Madison, Wisconsin.

The fifth section presents a summary of the research, the major conclusions, and recommendations for further research.

2.0 INCENTIVE POLICIES: DESCRIPTIONS AND RECENT ENACTMENTS

The following seven types of incentive policies were selected for analysis:

(1) DIRECT GRANT
(2) INCOME TAX CREDIT
(3) PROPERTY TAX REDUCTION
(4) SALES TAX REDUCTION
(5) INCOME TAX DEDUCTION FOR DEPRECIATION
(6) LOAN INTEREST SUBSIDY
(7) TAX ON CONVENTIONAL ENERGY

These seven were selected because a review of current legislative activity revealed that these were the principal types of incentives under consideration both at the state and federal level. As is shown below, there is some legislative precedence for these seven incentives, each of which will be briefly described and discussed in turn.

2.1 Grants

The first type of incentive listed, i.e., a direct grant to the purchaser of a solar energy system, is being used in conjunction with two federal programs as well as by a number of states. The Solar Demonstration Program, administered by the U.S. Department of Housing and Urban Development (HUD), involves an expenditure of approximately $1 million in grants for the installation of solar units in 143 new and existing dwellings in 27 states.[1] The Energy Conservation and Production Act, which authorizes HUD to "undertake a national demonstration program designed to test the feasibility and effectiveness of various forms of financial assistance for encouraging the installation (of)... approved renewable-resource energy measures in existing dwelling units," specifies grants not to

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[1] U.S. Department of Housing and Urban Development, HUD News, HUD Press Release No. 76-22, Washington, D.C., January 19, 1976.

exceed the lesser of $2,000 or 25 percent of the cost of the system installed.[1] At the state level, Montana is an example of a state which has established a special research and development fund to be used to award grants "to any person, educational institution or other organization" for the purchase of a solar energy system.[2] Other states such as California, Colorado, Hawaii, Florida, Iowa, Maine, New Mexico, New York, North Carolina, and Ohio have R & D programs similar to Montana's, which generally involve some provision for grants. However, in most cases the level of funding limits the grants by states to in-state universities and other non-profit organizations for undertaking specific research and development projects in solar energy. Neither state nor federal grants are now generally available to the average homeowner or business person who wishes to install a solar energy system.

2.2 Income Tax Credit

The second type of incentive listed, i.e., the income tax credit, involves the reduction of the recipient's income tax liability by a specified amount. Aside from possible differences in timing, the income tax credit is essentially the same as a direct grant, as long as the recipient receives any excess of the tax credit over the amount of his or her income tax liability. For example, suppose a tax credit of $2,000 is allowed to the pruchaser of a solar energy sytem whose personal income tax liability is only $1,500. If the purchaser receives a check for $500, in addition to the waiver of income taxes owed, he or she will have received the equivalent of a cash payment of $2,000. Because of the close similarity of the direct grant and the tax credit in their impacts on costs, they are treated as identical in the life-cycle cost model and in the case studies of this report.

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[1] U.S. Congress, Energy Conservation and Production Act, PL 94-385, 94th Congress, 42 USC 6801, August 14, 1976, Title IV, Part C, Sec. 441.

[2] National Conference of State Legislatures Energy Task Force, Turning Towards the Sun, p. 16.

New Mexico, the only state which currently provides this type of incentive, allows to any taxpayer who installs a solar energy system in his or her personal residence in the state an income tax credit of $1,000 or 25 percent of equipment cost (whichever is less) with a refund if the tax credit exceeds the taxpayer's state income tax liability.[1]

Under existing federal tax law, solar energy systems generally do not qualify for the investment tax credit that is allowable on some types of business equipment investments.[2] However, several bills are now pending in the U.S. Congress which would allow income tax credits for purchase and installation of solar energy systems. For example, H.R. 6860, a bill now pending in the U.S. Senate calls for a refundable tax credit of 40 percent of the first $1,000 and 25 percent of the next $6,400 of qualified expenditures for solar heating and cooling equipment in residences, with a cash payment of any excess of tax credit over tax liability. The bill also allows for extension of the investment tax credit to cover solar energy equipment installed in commercial buildings. The amount of credit allowed is 20 percent of the initial investment costs incurred beginning January 1, 1977 through 1979, and 10 percent for those costs incurred through 1981.[3]

2.3 Property Tax Reduction

The third type of incentive, i.e., the reduction in property taxes, appears to be the most prevalent form of direct financial incentive now

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[1] Ibid., p. 10.

[2] That is, solar energy systems were generally not allowable under federal tax law in effect at the time of the completion of the analysis for this report, except if they comprised an integral part of a manufacturing or industrial process. (Title 26, U.S. Code, Secs. 38 and 48, Provisions as of June 1976.)

[3] U.S. Congress, Senate, Energy Conservation and Production Revenue Act of 1976, H.R. 6860 (A bill passed by the U.S. House on June 23, 1975, reported out by the Senate Committee on Finance on August 27, 1976, and now pending before the Senate).

being enacted at the state level. Currently, eleven states allow an exclusion of part or all of the value of a solar energy system for a period of time ranging from 5 years to the life of the system. These states are Indiana, Arizona, Colorado, Illinois, Maryland, Delaware, Montana, New Hampshire, North Dakota, Oregon, and South Dakota.[1]

2.4 Sales Tax Reduction

The fourth type of incentive, i.e., a reduction in the sales tax on solar energy equipment, is allowed by only one state. Texas exempts from state sales tax the receipts from selling, leasing, or renting solar energy devices.[2]

2.5 Income Tax Deduction for Depreciation

The fifth type of incentive, i.e., the allowance of an income tax deduction for depreciation on the capital costs of solar energy systems, can take several forms. One approach is to expand the current eligibility for capital depreciation deductions from businesses to include homeowners. Another approach is to increase the value of the depreciation, either by shortening the length of time over which the depreciation is written off against yearly tax liability,[3] or by otherwise allowing a more liberal

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[1] National Conference of State Legislatures Energy Task Force. Turning Towards the Sun, pp. 7-9.

[2] Ibid., p. 11.

[3] No specific life is set forth by the current provisions of the Internal Revenue Code for the depreciation of solar energy equipment. Existing practice is to base estimated life on the "facts and circumstances" system; that is, to determine life in individual cases on basis of the particulars of the given situation.

depreciation method.[1] The value of the write-off is increased by shortening the defined life of the system or by using a depreciation method which results in larger deductions initially because the tax savings are thereby obtained more quickly and can be put to profitable use.

Arizona now allows any taxpayer (business and homeowners) to write off the value of a solar device over a five year period for purpose of computing net income taxable by the state. It is the only state which has changed its capital depreciation allowance to encourage the use of solar energy.[2]

2.6 Loan Interest Subsidy

The sixth type of incentive, i.e., a subsidy to reduce the interest rate charged on loans to purchase solar energy systems, is not currently provided by any state government. However, a bill has been recently introduced in the U.S. Senate by Senator Edward Kennedy (S. 2932) that would provide a federal guarantee of funds for low interest loans to purchase solar energy systems--loans at 2% for residential application by low-income homeowners; loans at 5% for applications to residences, small businesses, and farm facilities by other income groups; and loans

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[1] Current regulations of the Internal Revenue Service allow for the use of a double declining balance method for computing depreciation on new commercial residential buildings and a 125 percent declining balance method on existing commercial residential buildings. On non-residential commercial buildings, a 150 percent declining balance method is allowed for new buildings, and a straight-line method for existing buildings. (Title 26, U.S. Code, Sec. 167(j).) In the opinion of several staff members of the Corporate Tax Division of the Internal Revenue Service who were interviewed, these regulations for depreciation of buildings would apply to solar energy systems attached to the buildings.

[2] National Conference of State Legislatures Energy Task Force, Turning Towards the Sun, p. 10.

at the current prime rate for other commercial applications. The bill calls for the loan funds to be administered by the states.[1]

2.7 Tax on Conventional Energy

The seventh and last incentive treated in the model is the imposition of a special tax on conventional energy sources. Because solar energy systems derive their economic value from the cost of alternative sources of energy, raising the price of the alternative sources (e.g., by imposing a new tax or by raising existing taxes) will increase the value of solar energy. California now has a surcharge of $0.00001 per kilowatt-hour on all electricity sold to consumers within the state. A portion of the revenue generated by the surcharge goes to support the solar research and development program.[2] In addition, the surcharge increases the appeal of solar energy relative to electricity (or any other fuel being so taxed), other things being equal.

2.8 Legislative Overview

The map in Figure 2 shows the states which have enacted solar incentive legislation. It indicates that the most prevalent form of direct financial incentive for solar energy has been the exemption of property taxes.

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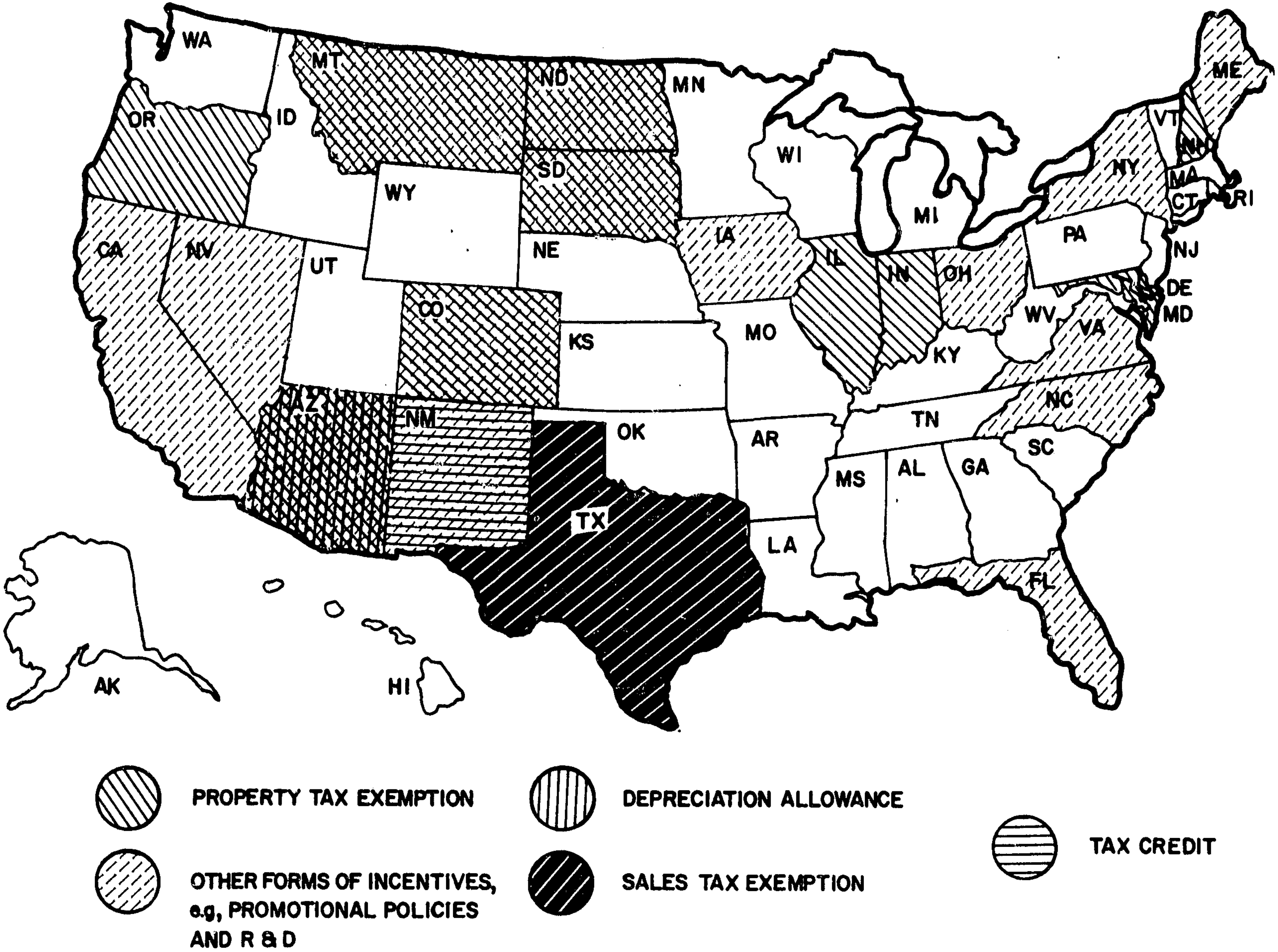
[1] U.S. Congress, Senate, Energy Conservation Act of 1976, S. 2932 (A bill introduced in the U.S. Senate by Sen. Kennedy on February 5, 1976, and now pending in the Senate Committees on Banking, Housing, and Urban Affairs; Commerce; and Interior and Insular Affairs).

[2] National Conference of State Legislatures Energy Task Force, Turning Towards the Sun, p. 12.

Figure 2

State Solar Legislation



Source: Robert M. Eisenhard, A Survey of State Legislation Relating to Solar Energy, pp 5, 6, 7.

3. LIFE-CYCLE COST EVALUATION METHOD

A life-cycle cost model can be developed for computing the annual net cost savings (or net losses) from a solar energy system with and without various incentive policies. By then comparing the results, it can be determined (1) if an incentive is needed to make solar energy economically appealing in the private market place, (2) what impact a given incentive will have, and (3) which among the different incentives being considered will come closest to having the desired impact.[1] In this chapter the life-cycle evaluation model is first explained in terms of its logic, and then a computer program for exercising the model is presented.

3.1 The Model

Investment in a solar energy system involves expenditures and savings which are spread out over the life of the system. It is, therefore, important to use an evaluation method which incorporates all cash flows over the life period. Because money has a time value and, accordingly, equal expenditures or savings made at different times do not have the same value, it is also important to use an evaluation method which

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[1] This assumes that the policy makers have some notion as to the amount of cost savings required to elicit a strong market response. Normally, it might be assumed that the investment would be attractive if the rate of return were equal to or exceeded that generally available on alternative available investments. However, in the case of a new technology such as solar energy systems, the "nuisance" cost of obtaining the system, and the uncertainty regarding its performance and resale value might require a premium return in order to make people willing to purchase them. The question of market response to varying degrees of profitability is not addressed by this study. Also not addressed is the impact of government efforts to reduce perceived risks associated with solar energy systems, through subsidies to R&D and informational and promotional programs.

converts all cash flows to a common point in time.[1] The life-cycle cost evaluation method described here accomplishes both the comprehensive accounting of cash flows and the conversion of cash flows to an equivalent basis.

Figure 3 indicates the main elements contained in the life-cycle cost model which is used to derive annual net savings or losses from a solar heating system. These cost elements apply to all components and related aspects of the healing system, including the solar collection panels, thermal storage, distribution system, control system, occupied living space, and any building modifications.[2] The model allows the analyst to calculate and compare total life-cycle costs against total life-cycle savings, to compute the net difference, and to express the results in terms of a uniform annual net savings or loss. For example, an annual net savings of $100 from a system expected to last 20 years

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[1] Given the appropriate interest rate, we can apply compound interest formulas (or the equivalent interest factors) to receipts, savings, or disbursements to convert them to equivalent sums at a specific date. A separate factor which may necessitate the adjusting of cash amounts with respect to time of occurrence is changes in the purchasing power of the dollar, i.e., inflation. For an in depth explanation of methods to deal with the time value of money and inflation, see an engineering economics textbook, such as Gerald W. Smith, Engineering Economy: Analysis of Capital Expenditures, 2nd ed. (Ames, Iowa: The Iowa State University Press, 1973).

[2] The basic application of life-cycle costing to solar energy systems is explained in some detail in an earlier report (See Rosalie T. Ruegg, Solar Heating and Cooling in Buildings: Methods of Economic Evaluation). This report begins the further development of the life-cycle cost model at essentially the point that the earlier report ended, and provides a computer program that facilitates its application.

Figure 3

Elements in the Life-Cycle Model

- DIRECT COSTS
  - Purchase & Installation
    - Down payment
    - Loan fee
    - Loan principal & interest
  - Maintenance
  - Repair & Insurance
- DIRECT COST SAVINGS
  - Fuel Cost Savings
- OTHER EFFECTS
  - Property Taxes
  - Sales Taxes
  - Income Tax Deductions

means that the net effect of the investment is the same as saving \$100 each year for 20 years above and beyond all costs required to realize the savings.[1]

Following is the algebraic statement of the life-cycle cost model. This model is designed to be used to assess the economic performance of a solar heating system both with and without incentives. That is, the model's capability for evaluating the impact of incentives does not preclude its use to evaluate the cost effectiveness of solar heating systems in general. Furthermore, with only slight modifications, it serves for the analysis of both residential and commercial applications.

ANNUALIZED
NET
SAVINGS = FUEL COST SAVINGS —— ACQUISITION

$$AS = [E \cdot X \cdot N \cdot F(1) \cdot q \cdot k(1) \cdot t] - [k(1)((C \cdot D) + (S \cdot L) + B) + (k(2) \cdot L)$$

MAINTENANCE AND REPAIR —— REMAINING TAX EFFECTS

$$+(M + NI)] - [R + V - U - W + Z]$$

where

AS = Annual net savings from the solar energy system over a designated period of time, N.

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[1] With simple modification the life-cycle cost equation could be formulated to derive present value net savings or losses, whereby the net difference between all costs and all savings over the life of the system is stated in terms of an equivalent single amount incurred today. In addition, other measures of the economic performance of solar energy systems, such as the internal rate of return and the payback period, could be derived using essentially the same input variables, but modifying the model formulation. The annual net savings method was selected over these other methods, because it is perhaps a more easily understood concept than the present value and rate of return methods, and is free from some of the shortcomings of the payback method. [For a discussion of the shortcomings of the payback period, see Gerald Smith, Engineering Economy: Analysis of Capital Expenditures, pp. 116 - 117].

E = Heating load of the building in therms, i.e., total BTU load $\cdot 10^{-5}$

X = Fraction of the heating load supplied by the solar energy system.

F(1) = Price of the conventional fuel at the time the solar energy system is installed.

q = A term to find the present value of the price of conventional fuel escalated over N years at an annual rate of Y, when the opportunity cost of capital is indicated by an interest rate of I; i.e., $q = \sum_{J=1}^{J=N} \frac{(1+Y)^J}{(1+I)^J}$.

k(1) = The capital recovery interest term used to convert the present value of a cost to an equivalent annual value, over N years with an interest rate of I; $k(1) = \frac{I(1+I)^N}{(1+I)^N - 1}$.

t = A term to adjust the price of fuel by the imposition of a tax; i.e., t = (1 + T(4)), where T(4) = the tax rate on fuel purchased.

C = Contract price for the solar energy system before sales tax is added, where $C = (A \cdot P) + B(1)A + B(2) - G = A(P + B(1)) + B(2) - G$, and A = collector area, P = collector purchase and installation price per ft^2, B(1) = variable cost of the non-collector components expressed as cost per ft^2 of the collector area, B(2) = fixed cost of the non-collector components, and G = grant or tax credit in present dollars, where any excess of the amount of a tax credit over income tax liability is fully refunded.

D = The down payment as a fraction of the contract price.

S = Loan settlement fee expressed as a percentage of the loan.

L = The dollar amount of the initial loan principal, i.e., L = (1 - D)C.

B = Building modification costs necessitated by the use of the solar energy system and/or the cost of living space occupied.

k(2) = The capital recovery interest term used to convert the present value of a loan to an equivalent annual payment, over N years, with a loan interest rate of I(1), i.e., $k(2) = \frac{I(1)(1 + I(1))^N}{(1 + I(1))^N - 1}$.

M = Annual maintenance and routine parts replacement costs.

NI = Annual insurance premium and damage repair costs, net of insurance reimbursements.

R = Annual property tax payment, net of state and federal income tax deductions, i.e., $R = (1 - T(1)) \cdot T(2) \cdot C$, where T(1) = personal or corporate composite state and federal income tax rate at the margin, T(2) = the effective property tax rate, and it is assumed that the contract price of the system (C) is representative of the market value of the system upon which tax assessment is based.

V = The dollar amount of sales tax to be paid on the contract price of the system, converted to an annual equivalent, i.e., $V = (1 - T(1)) \cdot T(3) \cdot C \cdot k(1)$, where T(3) = the sales tax rate.

U = The equivalent annual value of income tax deductions of total interest payments on the loan over N years, i.e., $U = \sum_{J=1}^{J=N} \frac{L(J)\cdot(I(1))}{(1+I)^{J}} \cdot k(1) \cdot T(1)$, where L(J) = the dollar amount of the loan principal in the Jth year, and I(1) = the loan interest rate. (In the computer program which follows, the parameters Q(1) and Q(2) are used to derive the value of U.)

W = the equivalent annual value of capital depreciation deductions from taxable income, based on the straight-line depreciation method, i.e., $W = \sum_{J=1}^{J=N(1)} \frac{C}{N(1)(1+I)^{J}} \cdot k(1) \cdot H \cdot T(1)$, where N(1) = the number of years over which the capital costs may be written off against taxable income; and H = 0, if no depreciation deductions are allowed, and H = 1, if depreciation deductions are allowed. Alternatively, depreciation can be calculated on the basis of some other method of depreciation, such as the declining balance method (see p. 11, footnote 3). Based on the declining balance method, the annual after-tax value of the deductions in the first year, D(1), is calculated as follows: $D(1) = \frac{Y(1)(C)}{N(1)(1+I)^{1}} \cdot k(1) \cdot T(1)$; and in the second year, $D(2) = \frac{Y(1)(C-D(1))}{N(1)(1+I)^{2}}$: etc, where $\frac{Y(1)}{N(1)}$ = the declining-balance rate.

Z = The equivalent annual value of the loss of income tax deductions from fuel costs saved, i.e., for commercial applications, $Z = E \cdot X \cdot N \cdot F(1) \cdot q \cdot k(1) \cdot t \cdot T(1)$; and for residential applications, $Z = E \cdot X \cdot N \cdot F(1) \cdot q \cdot k(1) \cdot T(4) \cdot T(1)$.

First, the model calculates the annualized dollar energy savings from substituting solar energy for conventional energy. This is done by pricing out that part of the energy load supplied by the solar energy system (i.e., $E \cdot X$), using a price which is adjusted to take into account future real increases over the period of analysis (i.e., $N \cdot F(1) \cdot q \cdot k(1) \cdot t$). The inclusion of a tax factor (t) in the fuel cost savings portion of the model allows us to take into account any existing sales tax on fuel, as well as to assess the impact of a special "incentives" tax on fuel.

To avoid further complexity in an already detailed model, the energy analysis is based on heating by solar energy only. However, the model could easily be expanded to take into account solar heating of domestic water and/or solar cooling.

The model assumes that the solar heating system's auxiliary energy system is the same in kind and size as would be the conventional energy system used alone. Thus the capital investment required for the solar heating system is assumed to be above and beyond that required for the conventional energy system.

In its second portion, the model calls for calculation of acquisition, maintenance, and repair costs, taking into account financing costs, building modifications, and insurance costs.[1] A term (see the definition

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[1] An additional cost item, which is not included in the above equation but is presently an important factor, is "search" cost. Search cost refers to the cost of determining the technical suitability of a solar system for a given building, of determining the availability of solar designs, and of arranging for maintenance, etc.

of "C") is included in this portion of the model to enable the assessment of the impact of grants or tax credits on acquisition costs.

Third, the model calculates each of several remaining tax effects, including the effects of the property tax (R); the sales tax (V); and the deductions of interest payments (U), capital depreciation (W), and current operating costs (Z) from taxable income.

As was noted above, this model serves for the analysis of both residential and the commercial applications of solar heating. The only change in the formulation comes in the last term, Z (see the definition of terms following the equation). This change is necessary because homeowners generally are allowed no deduction for their expenditures on energy use in the home (aside from the deduction of applicable sales tax), whereas commercial owners are allowed to deduct their expenditures for conventional energy supplies to the building as a business expense. Thus, the loss of income tax deductions for fuel costs, which results when solar energy displaces conventional energy, is negligible for homeowners, but substantial for businesses. Accordingly, the term Z is defined differently for homeowners and for businesses.

Otherwise, the cost differences in the residential and commercial use of solar heating systems are reflected in the values assigned to the parameters (e.g., the appropriate income tax rates and discount rates may differ between residential and commercial analyses).

3.2 The Computer Program

The computer program to exercise the model is written in BASIC[1] language. This is an algebraic programming language that allows the

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[1] "BASIC" is an acronynm for Beginners All-purpose Symbolic Instruction Code. For a description of the use of BASIC, see BASIC LANGUAGE, Honeywell Software Series 400, Honeywell Information Systems, Inc., August 1971.

user to submit a program in a time-share environment, in ordinary mathematical notation.

The program format is designed to allow the analyst running the program on a teletypewriter terminal maximum flexibility in specifying the values of the critical parameters. The following parameters are entered in the program as "input statements": the size of the collector; the collector price per ft^2; the fixed and variable costs of the non-collector components; the building's heating load; the expected performance of the solar energy system in terms of the percentage of the load provided; the mortgage interest rate; the opportunity cost of capital (discount rate); the time horizon of the analysis; the property, sales, and income tax rates; the present price of fuel and its expected future rate of increase; and the provision of special incentives. The input statement allows the person running the program to supply the values of the parameters through the teletypewriter keyboard while running the program. This format was convenient in undertaking the case studies in that it allowed the parameters to be changed in successive runs to fit the particular circumstances of each case. This same format may also be convenient for the analyst at the national and state levels who are analyzing the impacts of incentives on costs for different solar energy systems, building sizes, income groups, and fuel costs. However, at the same time that it gives flexibility, the extensive use of input statements makes the program execution tedious for the analyst who wishes to make a large number of program runs. If some of the input values are to remain constant over a number of runs, the analyst will probably wish to modify the program to change those input statements which are to remain constant to "data statements," in order to have the data entered automatically.

Following is a listing of a computer program that can be used to exercise the life-cycle cost model. It is given for the residential case, with the necessary changes for the commercial case shown following the main listing.

BASIC Program for the Life-Cycle Cost Analysis of a Solar Energy System for an Owner-Occupied Residence

```
 5 LET W = 0
10 LET F = 0
15 LET U = 0
20 PRINT "INPUT COLLECTOR AREA"
25 INPUT A
30 PRINT "INPUT COLLECTOR PRICE / SQ FT"
35 INPUT P
40 PRINT "INPUT NONCOLLECTOR FIXED PRICE"
45 INPUT B(2)
50 PRINT "INPUT NONCOLLECTOR VARIABLE PRICE PER SQ FT COLLECTOR"
55 INPUT B(1)
57 PRINT "BUILDING MODIFICATION COST"
58 INPUT B
60 PRINT "INPUT GRANT"
65 INPUT G
70 LET C = A * (P + B(1)) + B(2) - G
75 PRINT "FRACTION OF DOWN PAYMENT"
80 INPUT D
85 PRINT "DISCOUNT RATE"
90 INPUT I
95 PRINT "NUMBER OF YEARS"
100 INPUT N
105 PRINT "LOAN INTEREST RATE"
110 INPUT I (1)
115 PRINT "INCOME TAX RATE STATE AND FEDERAL COMPOSITE"
120 INPUT T(1)
125 PRINT "INPUT PROPERTY TAX RATE"
130 INPUT T(2)
135 PRINT "INPUT SALES TAX RATE"
140 INPUT T(3)
```

```
141 PRINT "INPUT  FRACTION FOR LOAN SETTLEMENT FEE"
142 INPUT S
143 PRINT "INPUT FUEL TAX RATE"
144 INPUT T(4)
145 PRINT "# OF YEARS OF DEPRECIATION WRITE-OFF"
150 INPUT N(1)
155 PRINT "TYPE 1 IF DEPRECIATION IS ALLOWED OR TYPE 0 IF NOT"
160 INPUT H
161 PRINT "REPAIR AND INSURANCE COST"
162 INPUT NI
163 PRINT "MAINTENANCE COST"
164 INPUT M
165 PRINT "INPUT HEATING LOAD IN THERMS"
170 INPUT E
175 PRINT "INPUT FRACTION OF LOAD SUPPLIED BY SOLAR"
180 INPUT X
185 PRINT "INPUT FUEL PRICE ESCALATION RATE"
190 INPUT Y
195 LET K(1) = (I*(1 + I) ↑ N)/((1 + I) ↑ N - 1)
200 LET K(2) = (I(1)*(1 + I (1)) ↑ N)/((1 + I(1)) ↑ N - 1)
205 LET R = (1 - T(1))*T(2)*C
210 LET V = (1 - T(1))*T(3)*C*k(1)
215 PRINT "FUEL COST PER THERM IN YEAR 1"
220 INPUT F(1)
225 FOR J = 1 TO N
230 LET F = (F(1)*(1 + Y) ↑ J/((1 + I) ↑ J)) + F
235 NEXT J
240 LET F = F*K(1)
242 LET Q(1) = (1 - D)*C
243 FOR J = 1 TO N
244 LET Q(2) = Q(1)*I(1)
246 LET U = Q(2)/(1 + I) ↑ J + U
247 LET Q(1) = Q(1) - ((1 - D)*C*K(1) - Q(2))
248 NEXT J
249 LET U = U*K(1)*T(1)
260 FOR J = 1 TO N(1)
265 LET W = (C/(N(1)*(1 + I) ↑ J)) + W
270 NEXT J
275 LET W = W*K(1)*H*T(1)
280 LET V(1) = E*X*F*(1 + T(4))
285 LET V(2) = (D*C + S*(1 - D)*C + B)*K(1) + (1 - D)*C*K(2) + NI + M
290 LET V(3) = R + V - U - W + E*X*F*T(4)*T(1)
295 PRINT V(1), V(2), V(3)
300 AS = V(1) - V(2) - V(3)
305 PRINT "NET ANNUAL COST SAVINGS", AS
310 END
```

Modifications to the Program for the Life-Cycle Cost Analysis of a Solar Energy System for a Commercial Building[1]

```
290 LET V(3) = R + V - U - W + E*X*F*(1 + T(4))*T(1)
```

---

[1] If a solar-equipped rental building were to yield more rental income than its conventional counterpart, it might be desirable to amend further the above program to reflect the extra annual income. For a discussion of the evaluation of rental income differences, see Rosalie T. Ruegg, *Solar Heating and Cooling in Buildings: Methods of Economic Evaluation*, p. 21.

A further modification could be made to calculate the value of the depreciation writeoff by means of the declining balance method--the more frequently used method of depreciation in commercial buildings--instead of the straight-line method. To do this, lines 191 and 192 below should be added and lines 260-270 below should be substituted for the above lines 260-270. (The "declining balance depreciation variable' (lines 191 and 192) indicates the rapidity with which the capital value of the asset is to be written off, e.g.,Y(1)= 2 indicates a double declining balance.)

```
191 PRINT "DECLINING BALANCE DEPRECIATION VARIABLE"
192 INPUT Y(1)

260 LET W = 0
262 LET X1 = C
264 FOR J = 1 TO N(1)
266 LET X2 =(Y(1)/N(1)* X1/(1 + I)↑ J
268 LET X1 = X1 - X2
269 LET W = W + X2
270 NEXT J
```

4. CASE STUDIES

Following are case study evaluations of the seven incentive policies based on two climate locations and two types of buildings. The case studies are presented in order to illustrate the use of the evaluation method presented in Section 3, and to determine the effectiveness of the seven incentive policies under a representative set of conditions.

First the basic assumptions are set forth. Then the case studies for an owner-occupied residence are given, followed by the case studies for a commercial building.

4.1 Assumptions

Climate regions typical of Madison, Wisconsin and of Albuquerque, New Mexico are assumed for purpose of the case studies. Solar equipment costs, fuel prices, and tax rates which are typical of those found in many parts of the country (but not necessarily those typical of Madison and Albuquerque) are assumed for both climate regions. (These are given in detail below.) The case studies are representative rather than actual case examples.

The evaluation model is used to analyze the costs of an owner-occupied residence and a commercial building. To maintain comparability of the results, the residential and commercial buildings are assumed to be of equal size, with equal heating loads, and the solar energy systems are assumed to be of identical type and size, with the same performance.[1]

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[1] The building and solar energy system are held constant for the residential and commercial cases in order to compare the differential effects on costs of the existing tax structure and of incentives. However, in practice the required collector area and storage capacity per building area may differ significantly between residential and commercial buildings due to differences in building design, occupancy, and use. There may also be important economy-of-scale and other differences between the installation of solar energy systems in large commercial buildings and in houses.

In both the residential and commercial cases, the building is assumed to contain 1500 ft^2 of floor area and to have a heat loss factor of 10 Btu's per ft^2 per degree day.[1] This heat loss factor implies a well-insulated residence and a somewhat less well-insulated commercial building.[2]

The cost estimates are for a "typical" solar heating system with liquid solar collectors, water tank thermal storage, and a heat exchanger. It is assumed to be used in conjunction with a full auxiliary backup system which may be of any type, e.g., a gas or oil fired furnace or an electric resistance system, with a forced air heat distribution system.[3]

The collector, sized at one-third the floor area, is assumed to supply 47 percent of the heating load in Madison, and 75 percent of the heating load in Alburquerque.[4] The collector size is held constant for the two locations in order to focus on the comparative impact of the incentive policies. It is, however, unlikely that the same sized system

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[1] A degree day (DD) of heating is a unit used in specifying the nominal heating load of a building and estimating fuel consumption. For any one day, when the mean temperature is less than 65°F (18°C), there exist as many Degree Days as there are Fahrenheit (Celsius) degrees difference in temperature between the mean temperature for the day and 65°F (18°C). (5/9 $DD^F = DD^C$)[ASHRAE Handbook of Fundamentals, ASHRAE, New York, N.Y., 1972].

[2] An unpublished study by the Thermal Engineering Section, Center for Building Technology, National Bureau of Standards, of heating loads for a large sample of existing office buildings showed the heat loss factor to average approximately 10 Btu/ft^2/degree day.

[3] The system characteristics and technical performance are based on that described by J. Douglas Balcomb and James C. Hedstrom in "A Simplified Method for Sizing a Solar Collector Array for Space Heating" (A paper presented at the Solar Heating and Cooling Workshop (Western Region) Los Angeles, California, January 24-28, 1976, pp. 6 and 8.

[4] Ibid., p. 8.

would be optimal for both Albuquerque and Madison. The cost effectiveness of the solar heating system in either place might be improved by altering the size or configuration of the system or by making further tradeoffs between the supply of heating to the building and energy conservation actions to the building envelope, as compared with the system design assumed for purpose of these case examples.[1]

The collector system is assumed to cost $10.50/ft^2 or a total of $5,250, of which $6.50/ft^2 is allocated to materials and $4.00/ft^2 to installation.[2] The cost of the noncollector components of the solar heating system, shown itemized in Figure 4, are estimated to total $1,700.[3] The contract price of the system, including labor and materials, totals $6,950, a fairly moderate price in today's market for solar heating equipment.

The system is assumed to last 25 years with no salvage value after that time. If sold at any time during the 25 years, it is assumed that the owner receives full compensation for the remaining net savings realizable from the system.[4]

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[1] Optimal sizing of a solar energy system can be determined by comparing the incremental costs of larger system sizes and of energy conservation in the building with the respective incremental savings in energy. For a discussion of the conditions for economic optimization of the solar energy system, see Rosalie T. Ruegg, Solar Heating and Cooling in Buildings: Methods of Economic Evaluation, pp. 35-39.

[2] This collector price of $10.50/ft^2 falls about midway in the range of prices quoted at a solar industry trade show (Solar Energy Industries Association Industry Conference and Trade Show, Sheraton Park Hotel, Washington, D.C., May 27-29, 1975).

[3] The method of estimating the costs of the noncollector components of the solar energy system is comparable to that used by G.O.G. Löf and R.A. Tybout in "Cost of House Heating with Solar Energy," Solar Energy, Vol. 14, Great Britain: Pergamon Press, 1973, p. 262. However, higher fixed and variable prices are used in the calculations than were used by Löf and Tybout.

[4] System durability is a matter of concern to purchasers of solar energy systems, and a question for which there is little empirical data. A further matter of concern is the resale market for solar energy systems.

Figure 4

Derivation of Contract Price

$\overline{C} = \overline{P} \times \overline{A} = \$10.50 \times 500 = \$5,250$

$\overline{S} = \overline{W} \times \overline{N} \times \overline{A} = \$.10 \times 10 \times 500 = \$500$

$\overline{F} = \overline{B} + \overline{D} \times \overline{A} = \$200 + \$.20 \times 500 = \$300$

$\overline{M} = \overline{E} + \overline{G} \times \overline{A} = \$100 + \$.40 \times 500 = \$300$

$\overline{H} = \overline{I} + \overline{J} \times \overline{A} = \$150 + \$.30 \times 500 = \$300$

$\overline{K} = \overline{K} = \$300$
$\underline{\overline{S} + \overline{F} + \overline{M} + \overline{H} + \overline{K} = \$1,700}$

Total Contract Price of the System =

$$\overline{C} + \overline{S} + \overline{F} + \overline{M} + \overline{H} + \overline{K} = \$750.00 + \$12.40(500) = \$6,950$$

where

$\overline{C}$ = total cost of the collector array,

$\overline{P}$ = price per ft^2 of the collector,

$\overline{A}$ = area of the collector in ft^2,

$\overline{S}$ = total cost of thermal storage,

$\overline{W}$ = cost per lb. of water in storage,

$\overline{N}$ = number of lbs. of water per ft^2 of collector area,

$\overline{F}$ = total cost of pipes and fittings for the system,

$\overline{B}$ = fixed cost of pipes and fittings per job,

$\overline{D}$ = variable cost of pipes and fittings stated in terms of incremental cost per ft^2 of collector,

$\overline{M}$ = total cost of motors and pumps,

$\overline{E}$ = fixed cost of motors and pumps per job,

$\overline{G}$ = variable cost of motors and pumps stated in terms of incremental cost per ft^2 of collector,

$\overline{H}$ = total cost of heat exchangers,

$\overline{I}$ = fixed cost of heat exchangers per job,

$\overline{J}$ = variable cost of heat exchangers stated in terms of incremental cost per ft^2 of collector.

Note: Cost data are assumed to include overhead and profit. The auxiliary system is assumed identical to the conventional system used alone and provides the distribution of heat to the building. It is assumed that no structural modifications are required to the building. (The cost relationships are based on those presented in G.O.G Löf and R.A. Tybout, "Cost of House Heating with Solar Energy."

For purpose of the example, it is assumed that the purchaser provides a down payment of 25 percent of the contract price, and obtains a 25 year loan for the remaining 75 percent. It is further assumed that an initial, one-time loan fee of 1.5 percent of the principal is charged, and that the loan is made at a market rate of interest of 9.5 percent. This interest rate was selected because it is about typical of the mortgage interest rates currently in effect; however, it should be regarded as illustrative only.[1] For purpose of illustration, it is estimated that the 9.5 percent rate reflects an expected inflation rate of 5.0 percent per year, and an administrative and risk factor of 1.5 percent, thereby resulting in a real[2] return to capital of approximately 3.0 percent.

In an investment such as this, the monthly mortgage payment is fixed and effectively declines in "real" terms in face of inflation. In contrast, other payments, such as energy costs, maintenance, and repair, are free to inflate with changes in the purchasing power of the dollar as well as with changing conditions of supply and demand. For a valid comparison, one must express all cash flows in either current or constant dollar terms and discount with either a market or real discount rate respectively.

In these case examples, the approach that is taken to deal with inflation is (1) to convert the market rate of interest to a real rate for pupose of calculating the effective mortgage loan payments, (2) to assume that all future costs, other than conventional energy prices,

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[1] For purpose of the case studies, the loan interest rate is assumed to be equal for homeowners and businesses; whereas, in fact, the rate would likely differ for businesses depending upon their size and financial standing.

[2] "Real" interest rates are expressed net of inflation; whereas, "market" interest rates include a factor to compensate for expected inflation.

remain constant in real terms and that conventional energy prices increase at a real rate of 5 percent per annum, and (3) to use a real discount rate to convert present and future cash flows to an equivalent uniform stream of annual values.[1]

To discount cash flows in the residential case examples, an interest rate of 3.0 percent is used. This is a real rate of interest, apart from inflation, to take into account the rate of return foregone from the next best investment. As noted above a real rate of 3 percent is equivalent to a market rate of interest of about 9.5 percent when inflation is 5 percent and the administrative/risk fee is 1.5 percent. To discount cash flows in the commercial case examples, an interest rate -- also in real terms -- of 10 percent is used. This is equivalent to a market rate of interest of about 16.5 percent.

There is considerable controversy as to what are the appropriate discount rates for evaluating different types of investments, and the above interest rates should be regarded only as illustrative of what might be appropriate in these case examples. The use of a lower interest rate to discount the homeowner's cash flows than the business'es cash flows reflects the assumption that the real after-tax yield on alternative investments is low for the "typical" homeowner as compared with the "typical" business.

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[1] For a discussion of the impact of price inflation on investment analysis, see Gerald W. Smith, Engineering Economy: Analysis of Capital Expenditures, Appendix G, pp. 545-552.

A set of "typical" tax rates are assumed. For the analysis of the impact of personal and corporate income tax liability on solar energy costs, a single composite rate which combines federal and state tax rates is used. For the analysis of the homeowner's investment, a marginal tax rate of 32 percent is used. This comprises a federal income tax rate of 28 percent at the margin (the incremental tax rate on taxable income in excess of $16,000, up to $20,000) and a state income tax rate of 5 percent at the margin, where state income taxes are deductible for purpose of computing federal income taxes. For the analysis of the commercial investment, a marginal tax rate of 51 percent is used. This comprises a federal corporate income tax rate of 48 percent and a state income tax rate of 5 percent at the margin, also where the state income taxes are deductible for purpose of computing federal income taxes.[1]

An effective before-incentives property tax rate of 3 percent is assumed. This would be equivalent, for example, to a nominal tax rate of 5 percent applied to an assessed value of 60 percent of market value. (Effective property tax rates commonly range between 1 percent and 4 percent of market value.)

A sales tax of 4 percent is assumed. This is applied both to the contract price of the solar energy system and to the price of fuel.

---

[1] Local income taxes are not taken into account.

The analysis of the net "savings or losses from the solar energy system is made for two initial prices of conventional energy -- a relatively moderate price of $.45 per therm (100,000 Btu's) of heat delivered and a relatively high price of $.90 per therm of heat delivered. Table 1 shows how these costs of energy per therm delivered translate into costs per unit of energy purchased, the cost measures with which most of us are more familiar. It can be seen from the table that a cost of $.45 per 100,000 Btu's delivered is equivalent to paying $.015 per kwh of electricity, $.38 per gallon of fuel oil, and $.27 per therm of natural gas, given the system efficiencies noted in the table. Similarly, a cost of $.90 per 100,000 Btu's delivered is equivalent to paying $.03 per kwh of electricity, $.76 per gallon of fuel oil and $.54 per therm of natural gas. The $.45 per therm of heat delivered is probably typical of gas and oil prices in many parts of the country, whereas, the higher cost of $.90 per therm is probably more typical of current electricity prices.

As was noted earlier, the price of fuel is assumed to escalate from these initial prices at a rate of 10 percent per year including inflation and 5 percent per year after inflation. This assumption results in a substantial price rise when compounded over the 25 year period.

Figure 5 summarizes the key assumptions regarding the building, the solar energy system, energy costs, and tax and interest rates.

In the case of the other cost elements included in the model of Section 3.1, the following assumptions are made for purpose of the case examples: (1) There are, on net, no building modification costs beyond

TABLE 1

Equivalent Fuel Costs Per 100,000 Btu Output[a]

TYPE OF HEATING SYSTEM	DOLLAR COST PER UNIT PURCHASED	
ELECTRIC RESISTANCE (3,413 Btu/kWh 100% System Efficiency)	.015/kWh	.03/kWh
#2 FUEL OIL (140,000 Btu/Gal 60% System Efficiency)	.38/gal.	.76/gal.
NATURAL GAS (100,000 Btu/Therm 60% System Efficiency)	.27/therm	.54/therm
	EQUIVALENT COST PER 100,000 BTU (THERM) Output	
	$.45	$.90

---

[a] Cost per 100,000 Btu output is calculated for gas, oil, and electric resistance heating as follows:

$$\text{Cost/100,000 Btu} = \frac{\text{100,000 Btu}}{\text{Btu content/unit} \times \text{system efficiency}} \times \text{\$ price/unit}$$

Figure 5

Key Assumptions: Residential & Commercial Case Studies

o BUILDING SIZE	1500 ft^2
o HEAT LOSS FACTOR	10 Btu/ft^2/DD
o "STANDARD" LIQUID SOLAR HEATING SYSTEM	
o COLLECTOR AREA	500 ft^2
o COLLECTOR PRICE @ \$10.50/ft^2	\$5250
o NON-COLLECTOR SOLAR COMPONENTS	\$1700
o TIME HORIZON	25 YEARS
o LOAN INTEREST RATES	9-1/2% Market Rate, Residential & Commercial 4-1/2% Real Rate, Residential & Commercial
o DISCOUNT RATES	3% Real Rate, Residential 10% Real Rate, Commercial
o "TYPICAL" TAX RATES	Personal income tax 32% Corporate income tax 51% Property tax 3% Sales tax 4%
o ENERGY COSTS	\$.45/Therm output (\$.015/KWH elec., \$.38/gal. oil, \$.27 therm gas) \$.90/Therm output (\$.03/KWH elec., \$.76/gal. oil, \$.54 therm gas)
o FUEL PRICE ESCALATION RATE	10% nominal rate, 5% real rate

the contract purchase and installation cost of the system. (2) The location of the solar water storage system does not require the sacrifice of otherwise valuable living space. (3) The repair and replacement costs of the solar energy system are equivalent, on net, to the cost of the insurance premium payments at a rate of 2.2 percent per $1000 of contract price; i.e., damage losses are assumed offset by insurance reimbursements. (4) Maintenance costs for cleaning and routinely servicing the system amount to $50 per year.[1]

It is also necessary for purpose of the case examples to specify the values of the various types of incentives. The assumed values are the following: (1) The grant or tax credit (the model treats them identically) is a one-time, initial lump-sum amount of $1,000. (2) The property tax incentive assumes a full exemption of the market value of the solar energy system (where the contract price is used as a proxy for market value) from the 3 percent effective tax over the life of the system. (3) The sales tax incentive consists of an exemption of the 4 percent sales tax on the contract price of the solar energy system. (4) The depreciation incentive comprises a straight-line, five year write-off of the contract price against both state and federal taxable income. For the residential case study, the pre-incentive condition is assumed to allow for no depreciation write-off; for the commercial case study, the pre-incentive condition is assumed to allow for a 25 year, straight-line write-off.[2] (5) The interest incentive constitutes a subsidy of 2

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[1] The $50 per year maintenance cost is an estimate made in consultation with experts in the solar energy field, and is not based on empirical data.

[2] As noted on p. 12, a declining balance method of depreciation is allowable under certain conditions, and the life of the system is determined according to the "facts and circumstances" of the situation. Hence, the current allowable write-off might be more favorable to the use of solar energy than that assumed here, although the assumption of a 25 year, straight-line depreciation is not unrealistic for many cases.

percent towards the loan interest charge, continuous over the 25 year life of the mortgage. Deducting the assumed inflation rate of 5 percent from the 9.5 percent market loan interest rate leaves 4.5 percent, and deducting the 2.0 percent interest subsidy results in a subsidized real loan interest rate of 2.5 percent. (6) The fuel tax incentive consists of an annual surtax of 20 percent levied on top of the existing price of fuel.

4.2 Case Applications

Table 2 shows the results obtained by using the life-cycle cost model to analyze the net savings to a homeowner and to a business from a solar heating system, given the stated conditions and the climates of Albuquerque and Madison.

The results are given in terms of the annual net savings (or annual net losses where a minus sign precedes the number) to be realized by the building owner under eight different conditions: (1) before any taxes and without incentives, (2) with existing taxes and without incentives, (3) with taxes and a grant or a tax credit of $1000, (4) with taxes and an exemption of the assumed 3 percent property tax, (5) with taxes and a 5 year depreciation tax write-off of the investment cost of the solar energy system, (6) with taxes and an exemption of the assumed 4 percent sales tax on purchase of the solar equipment, (7) with taxes and an interest subsidy of 2 percent on the loan for the purchase of the solar energy system, and (8) with taxes and a special tax on fuel of 20 percent.

TABLE 2

ANNUAL SAVINGS TO THE OWNER OF A SOLAR-EQUIPPED BUILDING WITH & WITHOUT INCENTIVES: CASE STUDIES[a]

			ANNUAL NET SAVINGS IN DOLLARS							
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BUILDING TYPE	SELECTED LOCATIONS	FUEL COST/ THERM	BEFORE TAXES & INCENTIVES	WITH EXISTING TAXES	GRANT OR TAX CREDIT $1000	PROP. TAX EXEMPT.	5 YR. DEPR. ALLOW.	SALES TAX EXEMPT.	INTEREST SUBSIDY 2%	FUEL TAX 20%
RESIDENTIAL	Albuquerque, NM (65 x 10^6 Btu)	$.45	-110	-190	-110	-50	-80	-180	-160	-140
		$.90	300	230	310	370	350	240	260	340
	Madison, WS (118 x 10^6 Btu)	$.45	-60	-140	-60	10	-20	-130	-100	-70
						130[c]				
		$.90	410	340	420	480	460	350	370	470
						600[c]				
COMMERCIAL	Madison, WS (118 x 10^6 Btu)	$.45	-220	-350[b]	-300	-250	-190	-330	-300	-310
						-90[c]				
		$.90	180	-150	-70	-40	10	-130	-100	-70
						110[c]				

[a] Note that this compilation of annual savings is based on a specific set of assumptions regarding such variables as cost and performance of the system, the heating load of the building, the future escalation of energy prices, and discount rates and tax rates; a different set of assumptions would produce different results.

[b] Use of a double declining balance method of depreciation and a 10 year life instead of a straight-line method and a 25 year life would reduce annual losses with existing taxes from $350 to $204.

[c] The annual savings or losses based on a combination of the two incentives bracketed.

Column (1) -- before taxes and without incentives -- is provided for comparison with column (2) -- the after-tax situation -- to demonstrate the strong impact on costs of existing taxes. The comparisons afforded by these case examples suggest that ignoring tax effects in evaluating solar energy systems, a practice which is frequently seen in the literature, can significantly distort the results. The remaining columns (3) through (8) show the net savings (or losses) with each incentive evaluated separately. To determine the impact of a particular incentive, one can compare its respective column with column (2).

For purpose of tracing through and comparing the outcomes of each of these eight conditions, let us look first at the case of the owner-occupied residence in Madison, heated conventionally with fuel costing $.45/therm. Column (1) shows an annual net loss accruing to the solar energy system of $60 on a before-tax basis, without incentives. Column (2) shows an annual net loss from the solar energy system after-taxes and without incentives of $140, more than double the before-tax net loss.

Moving on to column (3), we see that the provision of a $1000 grant or tax credit is insufficient to offset the inherent economic disadvantage of the solar energy system. Although the grant does reduce the annual loss by $80 on net, the system is still cost ineffective as compared with the conventional heating system powered by fuel at $.45/therm.

In column (4), we see that with the exemption of the property tax the solar energy system yields a small positive net annual savings of about $10. Thus, under the stated conditions, the property tax exemption improves the cost position of the solar energy system by $150 per year, making it a little better than a breakeven investment for the homeowner.

Column (5) shows that the 5 year depreciation write-off against federal and state income taxes improves the cost position of the solar energy system by $120 per year, thereby moving it near a breakeven position.

Shown bracketed between columns (4) and (5) is the annual net savings which result from combining the property tax exemption and the 5 year depreciation write-off, the two most potent of the incentives examined under the given conditions. In combination, these two incentives are sufficient in this case to change the homeowner's investment in solar energy from one of loss to one of profit.

Column (6) shows the impact of the sales tax exemption in this case to be slight (an improvement of $10 per year), and the solar energy system continues to be economically unattractive.

Column (7) shows that the provision of a 2 percent interest subsidy on the loan to purchase and install the solar energy system reduces the annual loss by $40, but nevertheless leaves the solar energy system decidedly cost ineffective. A factor which significantly reduces the impact of the interest subsidy is the existing allowance of taxpayer deductions of interest payments from taxable income. A homeowner in the

32 percent tax bracket at the margin, for example, will save only 68 percent (i.e., 1.00 - .32) of the before-tax annual value of an interest loan subsidy. (This effect also applies to certain of the other incentives.)

Column (8) indicates the effect of the only one of the incentives examined which impacts on energy cost savings rather than on system investment costs. In this case, imposing an additional 20 percent tax on fuel has an impact about the same as the $1000 grant; it cuts annual losses in half, but is insufficient to reverse the economic position of the solar energy system.

Figure 6 shows graphically the comparative impact of each incentive on the homeowner's cost in the Madison case example. The vertical line represents the breakeven point; the bars to the right of the vertical line measure net annual savings (over and beyond costs); the bars to the left measure net annual losses (over and beyond savings).

The following conclusions can be drawn from this case analysis: (1) Homeowners in a climate like Madison's who have the option of heating conventionally with fuel at moderate prices or heating with a solar energy system (which costs roughly $13.90 per square foot, including total collector and non-collector components, and supplies no more than about half the heating load) would probably find it substantially less costly to heat with a conventional system, other things being equal. (2) Employment of any one of the incentives examined[1] would probably be

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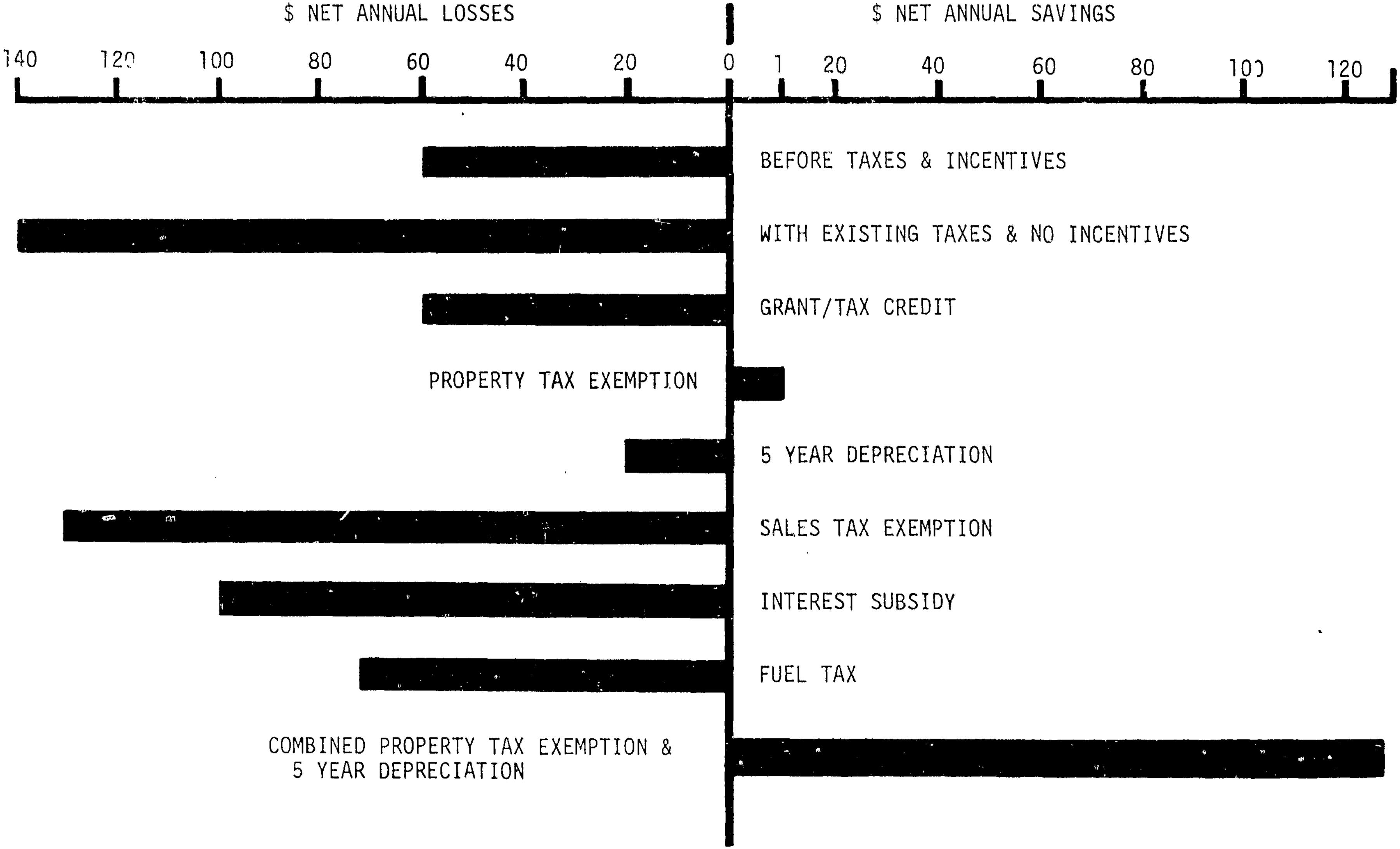
[1] Note that different values assigned to the seven incentives would change the relative impacts of these incentives.

Figure 6

Homeowner Savings or Losses: Madison Case Example, with Fuel Cost = 45¢/Therm



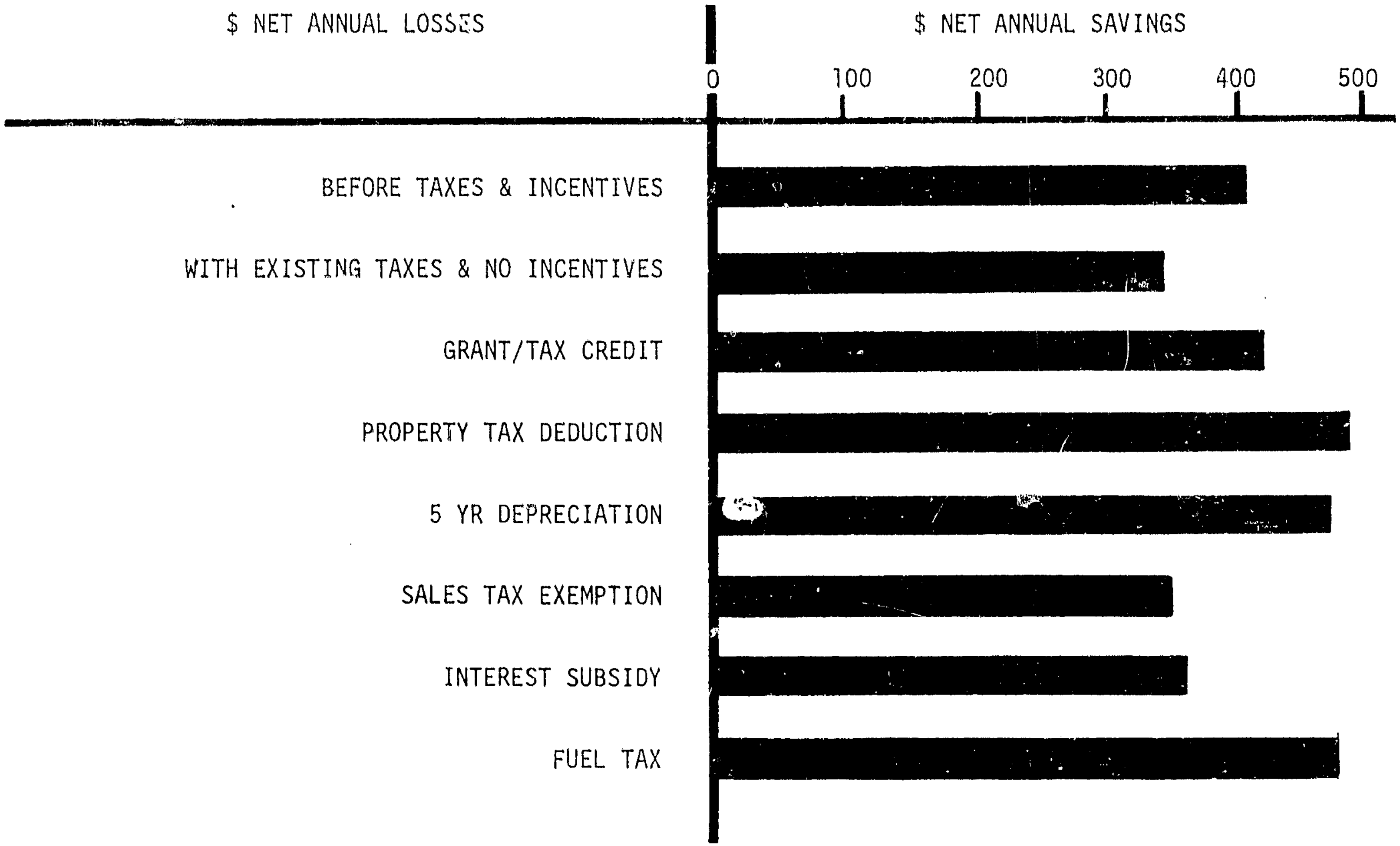
insufficient to create significant demand for solar energy. (3) By combining several of the more effective of the incentives, it appears possible to develop a strategy which would provide a strong profit incentive to homeowners to invest in solar energy systems.

Moving down one row in Table 2, we see the corresponding annual net savings from the solar energy system when all factors are held constant except that fuel prices are doubled. The annual net savings for this case example are displayed graphically in Figure 7. When evaluated against a price of $.90/therm for conventional energy and given the other conditions, solar energy is shown to be an extremely good investment. Even without incentives the second bar in Figure 7 shows that the homeowner would realize a substantial net savings after taxes of $340 per year. In this case, special incentives would appear not to be necessary to encourage homeowners to adopt solar energy systems because they are cost effective under existing conditions. Instead of incentives, what may be indicated in this case is a public information campaign to alert consumers, builders, lenders and other members of the building community to the potential savings to be realized from space heating with solar energy.

Comparing now the application of the same solar energy system to the residence in Albuquerque, we see results quite similar to the Madison case, although the system is on the whole somewhat less cost effective in Albuquerque than in Madison. The difference in annual net savings for the two locations reflects the differences in the technical performance of the system in the two locations together with the differences

Figure 7

Homeowner Savings or Losses: Madison Case Example with Fuel Cost = 90¢/Therm



in the annual heating loads. Recall that on the basis of an earlier study, this solar energy system was assumed to provide 47 percent of the space heating load in Madison and 75 percent in Albuquerque.[1] The house located in Madison, with its 7,863 degree days per year, will have an annual heating demand of almost 118 x 10^6 Btu, while the same house located in Albuquerque, with its 4,348 degree days per year, will have an annual heating demand of slightly more than 65 x 10^6 Btu. Thus, the energy savings is based on 47 percent of 118 x 10^6 for Madison (i.e., 55 x 10^6 Btu), and on the smaller amount, 75 percent of 65 x 10^6 Btu (i.e., 49 X 10^6 Btu), for Albuquerque. Given that investment costs, tax rates, and other relevant variables are assumed constant for both locations, the net savings will be larger in Madison where the energy savings are somewhat greater. Hence, other things being equal, it appears that a larger incentive would be required to promote solar energy systems in Albuquerque than in Madison.

Comparing now in Table 2 the net savings from solar energy for the owner-occupied residence in Madison with that for the commercial building in the same location, we see a rather dramatic difference in the two. The solar energy system is considerably less economically viable for the commercial building than for the counterpart, owner-occupied residence. The difference does not reflect differences in heating loads since these are assumed identical. Rather it reflects two factors: (1) the use of a higher discount rate in the commercial analysis to convert present and future costs to an equivalent basis, and (2) the current

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[1] Derived from Table III, Balcomb and Hedstrom, "A Simplified Method for Sizing a Solar Collector Array for Space Heating," p. 8.

tax laws which allow businesses to deduct conventional energy costs from taxable income. The effect of the existing tax treatment of energy costs is to reduce substantially the after-tax savings by the loss of the tax deductions on the energy saved. Given the relatively high income tax rates of most businesses, a sizable part of the savings (e.g., half when the tax rate is 50 percent) will be lost on an after-tax basis. These two effects make solar energy much less attractive in commercial applications than it otherwise would be. Looking, for example, at Column (2), we see that for a conventional energy cost of $.45/therm, the solar heating system on the commercial building results in net costs of $210 more per year than the counterpart residentially-applied system. For a conventional energy cost of $.90/therm, the commercially-applied solar energy system continues to lose on net, while the counterpart residentially-applied system is a substantial economic gainer. Figure 8 shows graphically the substantial net annual losses to the commercially-applied system when conventional energy costs $.45/therm, and Figure 9 compares for selected incentives the net annual losses to the business versus the net annual gain to the homeowner when conventional energy costs $.90/therm.

The life-cycle cost model can also be used to perform sensitivity analysis. Following are illustrative, albeit not exhaustive, examples of some of the perspectives from which an analyst may find it useful to examine incentives.

Rather than determine the impact of a single amount (i.e., $1000) of grant or tax credit, for example, one can analyze the impact of

Figure 8

Commercial Savings or Losses: Madison Case Example with Fuel Cost = 45¢/Therm

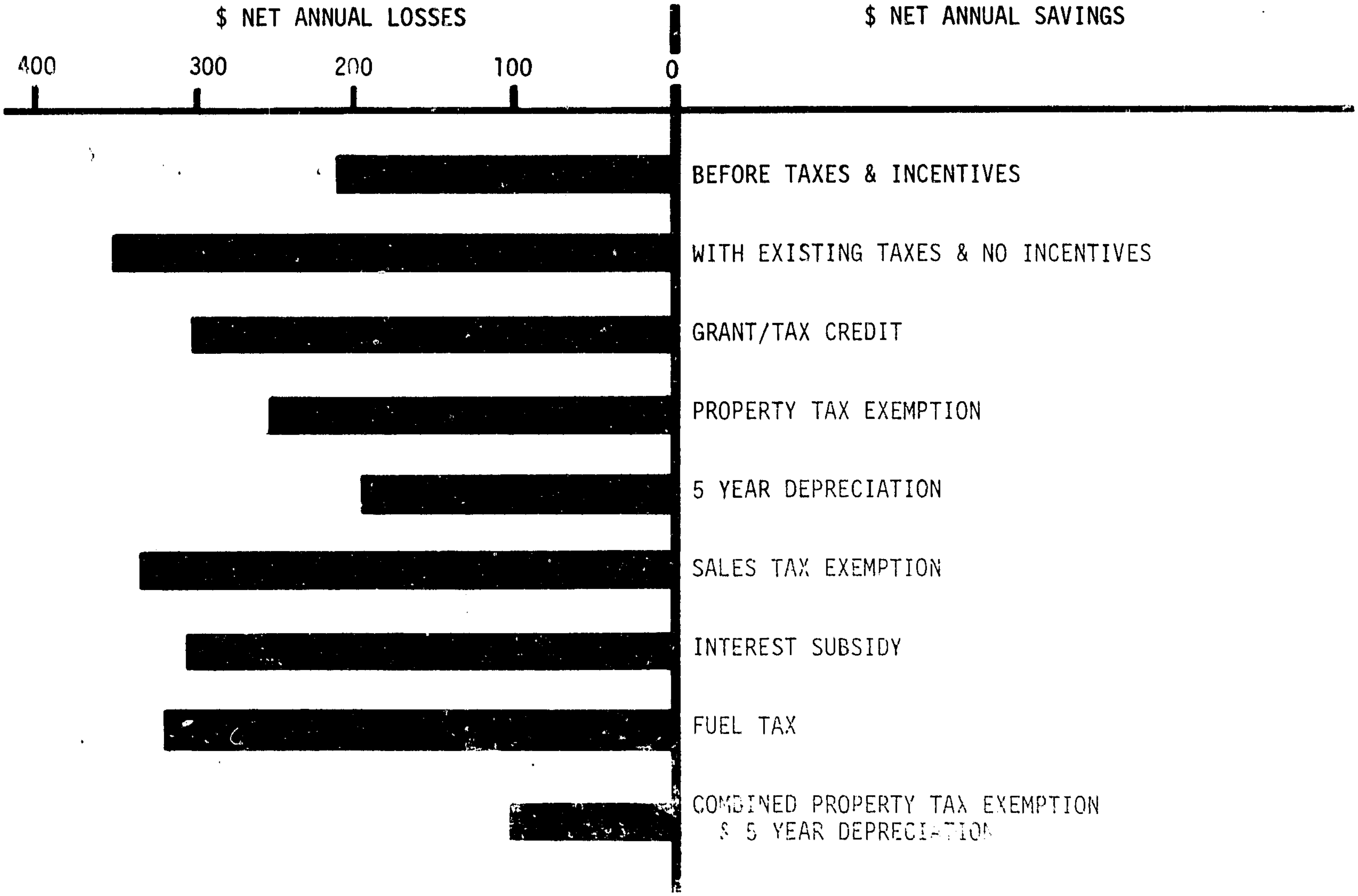
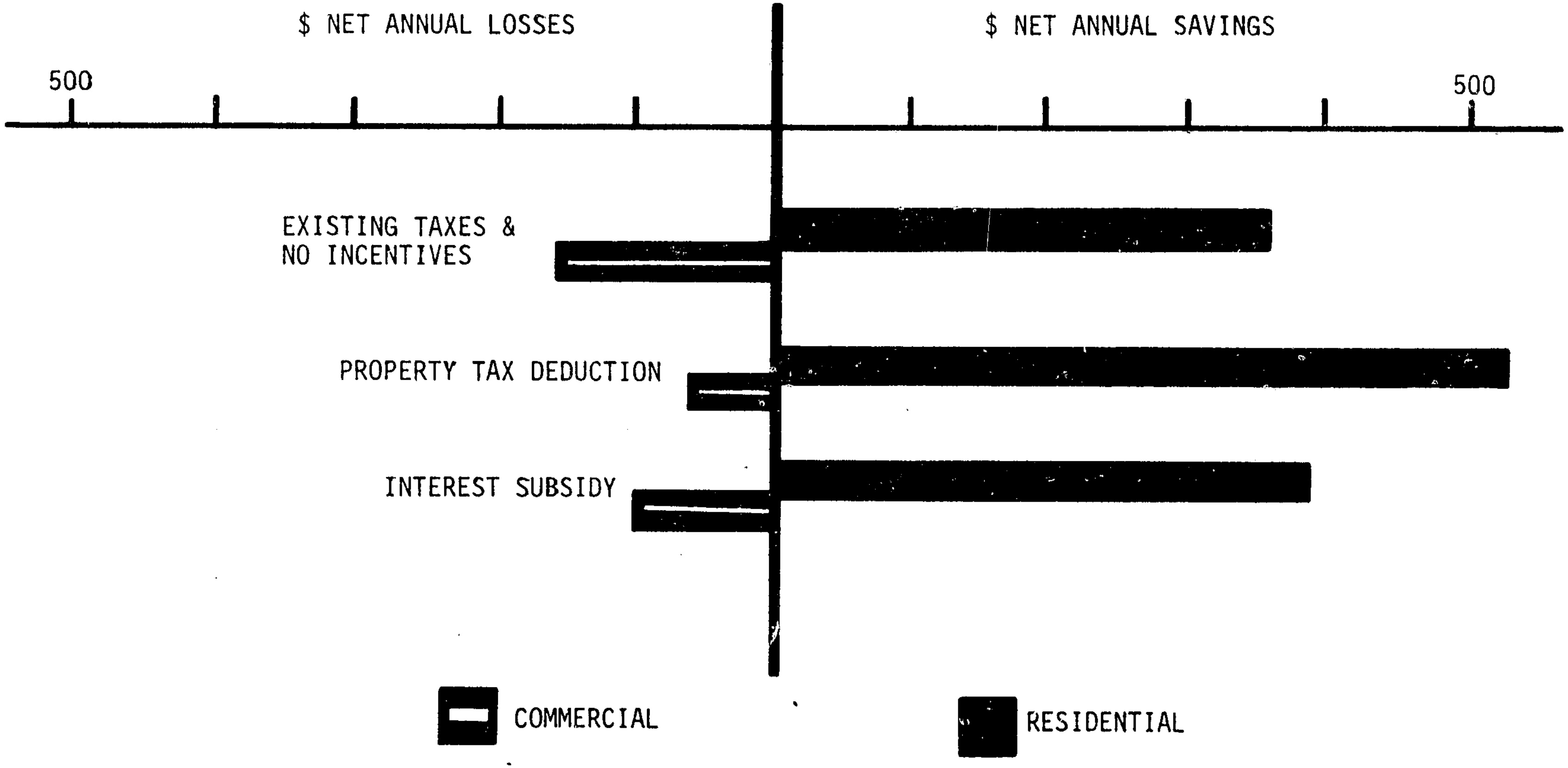


Figure 9

Comparison of Commercial and Residential Savings and Losses: Madison Case Examples with Fuel Cost = 90¢/Therm



different grant amounts or determine the break-even amount. Figure 10 was derived by running the life-cycle cost program for increasing grant amounts for the Madison commercial case example with energy costs of $.45 per therm. It shows the profitability of the solar energy system with different sized grants. A subsidy of nearly $5,000 is required to make the solar energy system break even in this case.

Figure 11 shows for the same case example how the gain in net savings from the exemption of property taxes depends upon the pre-exemption effective property tax rate and the market value of the solar energy system. As would be expected, the higher the market value and the tax rate, the stronger the solar incentive of property tax exemption.

Figure 12, also for the same case example, examines the gain in savings to the owner from the allowance of progressively faster write-off of solar equipment depreciation against taxable revenue. The graph shows, for example, that the owner's gain would be increased (or losses decreased) by the equivalent of more than $250 per year with a six year write-off as compared with having no depreciation allowance.

Additional sensitivity analysis could be performed to analyze the impact of alternative discount rates. In particular, it would be useful to determine the sensitivity of the differential in the residential and commercial cases to the use of differential discount rates.

The results of the commercial case examples as compared with the homeowner case examples suggests the following conclusions: (1) For equal sized buildings and heating loads, a larger incentive appears to

Figure 10

Net Annual Savings from Solar Energy With Various Grants/Tax Credits
Madison Commercial Case Study with Fuel Cost = 45¢/Therm

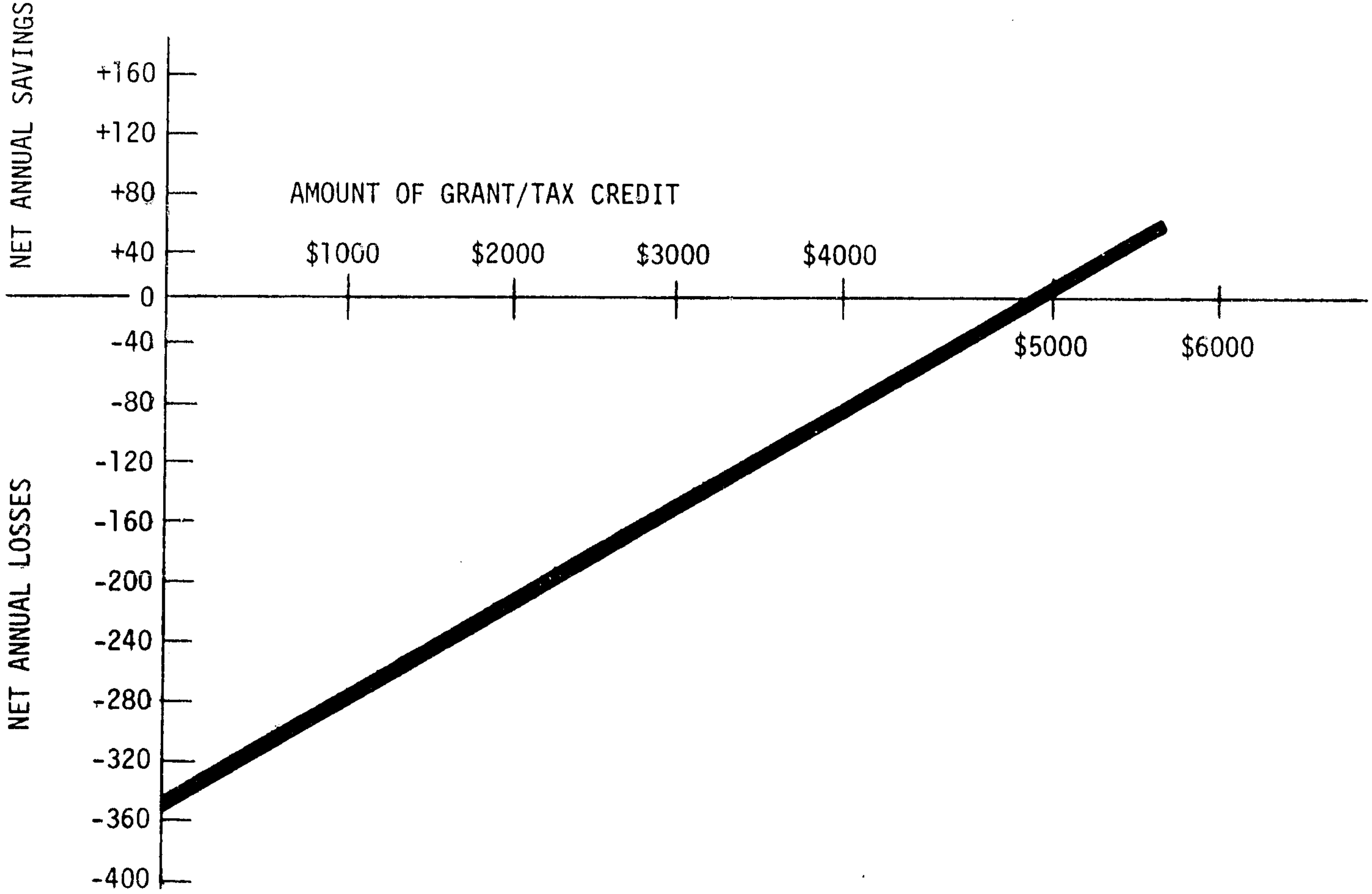


Figure 11

The Gain in Savings from Property Tax Exemption as Dependent Upon the Existing Property Tax Rate and the Cost of the Solar Energy System: Madison Commercial Case Study with Fuel Cost = 45¢/Therm

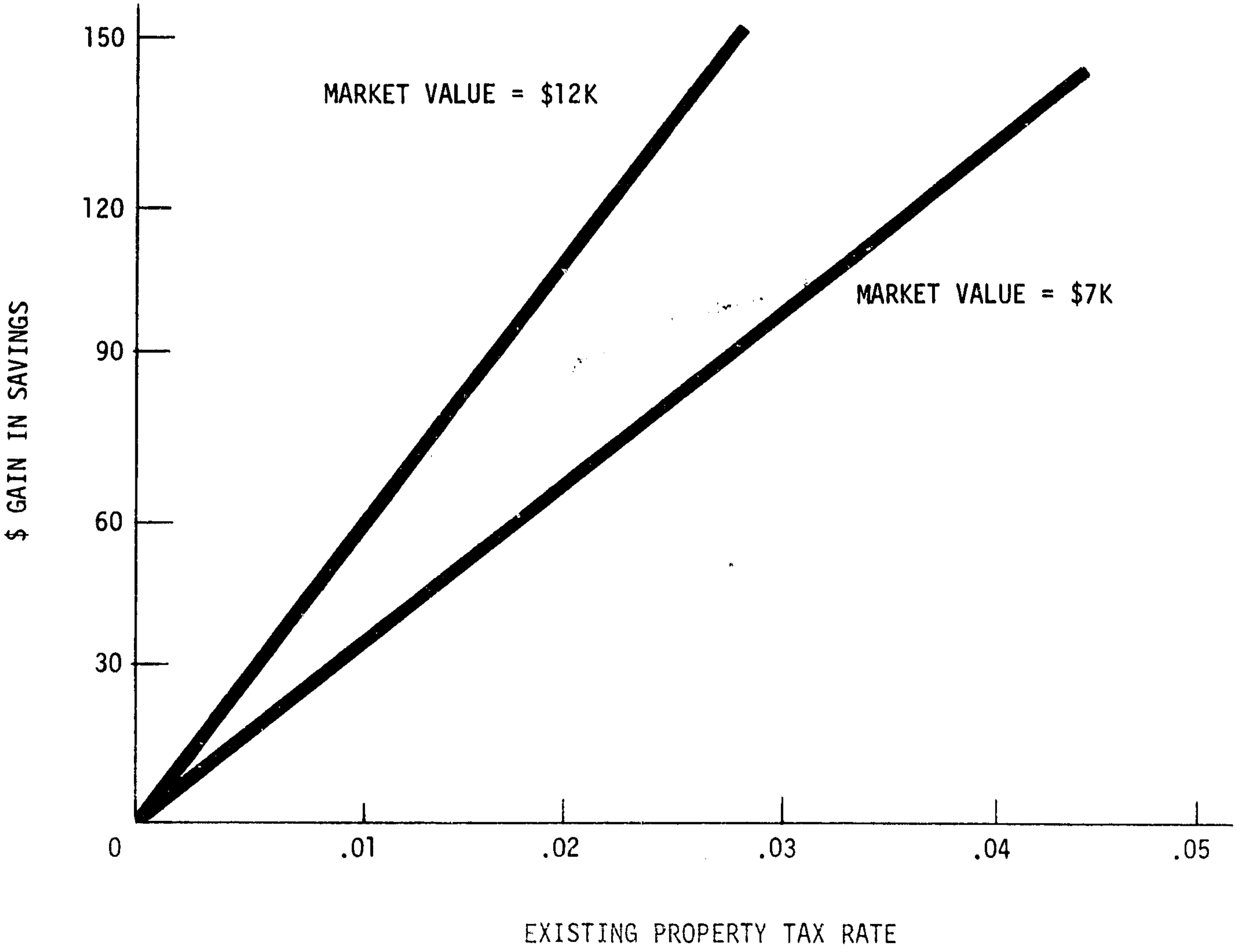
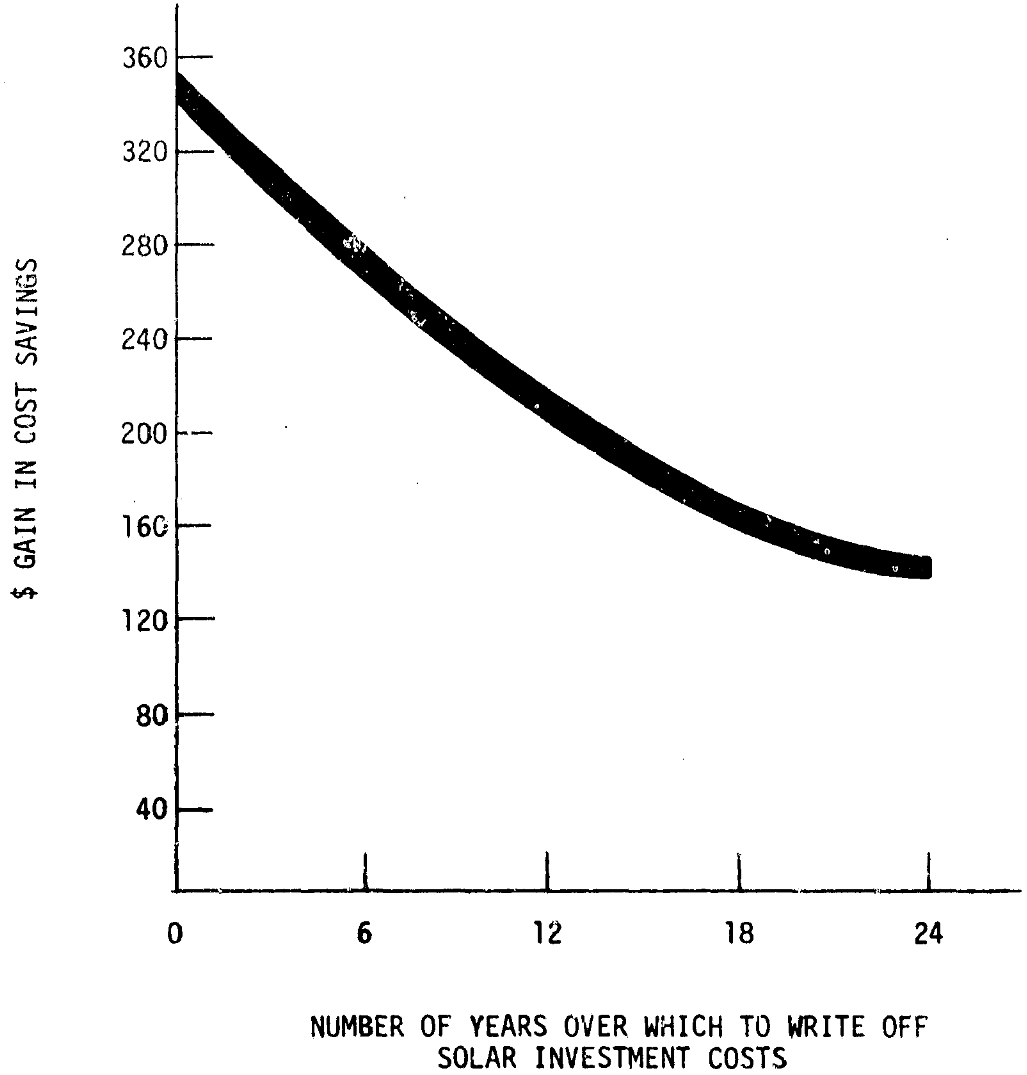


Figure 12

Relationship Between the Gain in Savings and the Depreciation Period:[a]
Madison Commercial Case Study with Fuel Cost = 45¢/Therm



[a] Based on use of a straight-line depreciation method.

be required to make solar energy cost effective for a business than for a homeowner. (2) As an alternative to the seven incentive programs considered here, policy makers might wish to consider measures to remove the existing bias in current income tax laws against commercial use of solar energy systems. This could be done, for example, either by eliminating the deduction of current conventional fuel costs as a business expense, or by allowing a counterpart tax deduction for the value of the conventional energy saved (i.e., the useful solar energy provided). (3) A difference in the impact of a given incentive on the commercial use of solar energy systems as compared with residential use, appears to have implications for the design of incentive programs. For example, provided that there is a comparable relationship for businesses and residences between solar energy system costs and energy saved, and if the current tax law which has the effect of taxing energy saved by businesses remains in force, it may be that more energy could be saved per government incentive dollar spent by directing incentive programs more towards homeowners than towards business. Further research into the comparative impacts of incentives on businesses and homeowners, therefore, appears to be warranted.

5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER RESEARCH

This report has provided and illustrated a life-cycle cost method for determining the impact of seven incentive policies on the cost of owning a solar heating system. The evaluation model and the conclusions drawn from the illustrative case examples should prove useful to state and federal legislative bodies which are currently formulating policies to encourage the widespread use of solar energy systems in buildings.

A review of current legislative activity aimed at developing solar energy incentives showed interest centering primarily on property tax exemption, grants, income tax credits, income tax deductions, sales tax exemptions, loan interest subsidies, and taxes on conventional energy sources. It was found that at least 12 state legislatures already have enacted some form of direct financial incentive for the purchase of solar energy systems, that 12 others have established somewhat more indirect programs of R & D and promotional activities in solar energy, while a number of other states and the U.S. Congress are in the process of formulating and enacting incentive legislation. There appears considerable opportunity to upgrade the effectiveness of these policies by performing quantitative assessment and comparisons of their cost impacts.

Because the impact of an incentive policy on the desire of people to own solar energy sytems depends on the pre-incentive economic performance of the system, a life-cycle cost model was developed which allows an overall net measure of the cost effectiveness of a system before and after an incentive is provided. A computer program in BASIC language was written to exercise the model.

Six case study evaluations were performed using the program, based on climates typical of Madison, Wisconsin and Albuquerque, New Mexico, and on representative solar equipment costs, fuel prices, and tax rates. The results of these case studies supported the hypothesis that the quantitative assessment and comparison of impacts are important in designing an economically effective incentive policy. More specifically, the results of the case studies suggested that the impact of incentive programs will be likely to vary considerably depending upon the climate region, the cost of conventional energy, and the type of building. It follows that the current practice of some states to duplicate the incentive programs of other states may result in inappropriate and/or ineffective incentive legislation. Some states will find the incentive policies now being enacted not worth the administrative costs required to implement them.

The case studies also dramatized the importance of considering tax effects in any cost evaluation of solar energy. The analysis of taxes suggested that changing tax policy to offset the negative effect of the current income tax treatment of business fuel expenses may be more important to encouraging the use of solar energy systems for commercial buildings than the enactment of the seven incentive policies considered here.

The model presented in this report may be viewed as a "micro-model," in that it is designed to analyze the impact of the selected incentives on an individual owner's costs. It offers the analyst a "do-it-yourself" approach with flexibility in specifying the values of parameters to fit particular state or regional conditions. It does not go further to project the nation-wide use of solar energy systems which might result from the enactment of different combinations of public incentive policies.

Suggested further work with this micro-model includes the development of "schedules of investment costs" and "schedules of energy cost savings" based on varying values of capital costs, fuel costs, energy loads, system performances, tax and interest rates, and incentives. Development of such schedules in tabular or nomograph form would provide a quick reference for estimating the cost effectiveness of solar energy systems under alternative conditions. Sensitivity analysis could be used to develop "impact profiles" for each type of incentive. It would appear that cost and impact schedules could help serve the needs both of state and federal decision makers and of building owners and the building industry for a quick means of estimating the economic performance of solar energy systems.

A potentially useful topic for further investigation is the comparative impact of incentives on residential versus commercial use of solar energy systems.

Other areas of further work lie in expanding the micro-model into a macro-model for analysis of national solar policy. Necessary work would encompass such areas as tests of market response to varying returns on investment in solar energy; development of frequency distributions of fuel costs, building types, and other key parameters in the model; and assessment of the administrative costs, equity effects, and other characteristics of incentive policies which are pertinent to the design of effective policies.

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U.S. DEPT. OF COMM.
BIBLIOGRAPHIC DATA SHEET

1. PUBLICATION OR REPORT NO. NBSIR 76-1127
2. Gov't Accession No.
3. Recipient's Accession No.

4. TITLE AND SUBTITLE

EVALUATING INCENTIVES FOR SOLAR HEATING

5. Publication Date September 1976
6. Performing Organization Code

7. AUTHOR(S)

Rosalie T. Ruegg

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.
11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*

NBS

13. Type of Report & Period Covered Final
14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report provides a life-cycle cost model and a computer program for measuring the dollar impacts of alternative incentives on the private costs of a solar heating system. In addition, it applies the evaluation model in six case examples, for seven selected incentives.

The purpose of the report is to assist state and Federal legislators in formulating effective policies for encouraging the widespread use of solar energy systems in buildings. It does this by promoting quantitative assessment of the kinds of incentive programs now being considered for adoption by many state legislatures and by the U.S. Congress.

The results of the case examples indicate that the effectiveness of a given incentive program will differ by region, by type of building, and by fuel prices; that in some states the incentive programs now being enacted will not be worth their administrative costs; and that an indepth assessment of policy implications should be made of the differential impact of incentive programs on residential versus commercial use of solar energy.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Cost analysis; cost effectiveness; incentives; life-cycle cost analysis; solar energy.

18. AVAILABILITY ☐ Unlimited

☒ For Official Distribution. Do Not Release to NTIS

☐ Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13

☐ Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED
20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED
21. NO. OF PAGES 61
22. Price