LBL-7805
UC-95c c. 2
TID-4500-R66

Energy and Environment Division

Subsidizing Solar Energy: The Role Of Tax Credits, Loans, And Warranties

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March 1978

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Prepared for the U.S. Department of Energy under Contract No. W-7405-ENG-48

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Work supported by the U. S. Department of Energy.

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I. Introduction

There seems to be fairly widespread agreement, both within the scientific community and among the general public, that solar energy is a "good thing," and further, that its use ought to be subsidized by appropriate governmental action. There is not, however, a consensus as to just why solar energy is desirable, or what constitutes appropriate action. In this paper we consider some arguments for a subsidy and relate them to a specific proposal.

In the next section we briefly review some of the arguments that have been advanced in favor of subsidizing solar energy. In section III we propose and discuss in some detail an additional argument, which seems to offer a strong rationale for a subsidy of a somewhat unconventional sort: a government-backed service warranty. The argument for the warranty is presented in section IV, along with an argument for a subsidy to overcome high front-end costs. In section V we present some estimates of the budget costs of a warranty program.

II. Why Subsidize Solar Energy?

Much of the current interest in solar energy stems from the recent run-up in prices of conventional fuels and uranium. As world oil prices increased about five-fold since the oil embargo of 1973, from roughly $2.50 per barrel to $12.50, in turn exerting pressure on coal and uranium prices, attention in the U.S. has turned to alternatives to these fuels. Direct solar conversion, in the form of rooftop solar collectors for the generation of hot water for space heating, has been prominent among the possible near term alternatives. But it is important to recognize that higher fuel prices are <u>not</u>, in themselves, arguments for government intervention in the energy sector. As a number of recent contributions by economists have pointed out, higher resource prices are a natural consequence of depletion of the particular resource, and lead private producers and consumers to seek substitutes--other, more abundant resources, other productive inputs like capital, and new technologies for extracting and converting the resource more efficiently, or using new resources.[1/] All of these adjustments in turn prolong the life of the scarce resource, and moderate its price rise.[2/] Thus, while it is natural enough for people to demand that the government "do something" about higher prices in the energy sector, this would not ordinarily be justified on grounds of economic efficiency. Rather, markets could be relied on to ration scarce resources and expand supplies.

Does this mean there are not grounds for intervention? Not at all. But we ought to be clear on what are, and what are not, grounds. If higher fuel prices in the abstract are not grounds, though, what of current prices? Clearly, to the extent that these reflect the monopoly power of the OPEC Cartel, they are not guides to socially efficient resource use. And given that it is not possible for the state of California or even the Federal Government to directly break the Cartel, and bring about free market energy pricing, other, second-best measures can legitimately be considered.

1/ For a clear nontechnical discussion see Solow (1974).

2/ In fact, until the recent monopoly-induced oil price increases, there was substantial evidence of declining real costs and prices for energy and other minerals over a fairly long period. See Barnett and Morse (1963) and Smith (1977).

One obvious set of measures, already being pursued in a number of ways, would be to encourage both conservation and certain aspects of the discovery and production of additional (domestic) energy supplies, to bring about a reduction in demand for energy imports. Several arguments can be made in favor of such an induced demand reduction. First, it puts pressure on the Cartel. Second, it can reduce the average cost of domestically consumed energy, even if Cartel prices hold firm. Third, it reduces U.S. dependence on insecure foreign sources of supply. These sources are equivalent to a lottery whose payoff is oil at the current world price with probability $p < 1$ and at some much higher price with probability $(1-p)$. A failure of the market to properly account for very low probability events, such as an embargo, would lead to an excessive reliance on imports.

But where does all of this leave solar energy? Specifically, is there any reason to put money into solar, instead of the proven conventional fossil and nuclear sources? We think there is. In fact, there are at least a couple of reasons. One will be discussed in the next section. The other we take up in the remainder of this section.

One difficulty, then, with subsidizing conventional sources in place of solar is that they are already, long before the current "energy crisis," heavily subsidized in a number of ways. Now, this does not <u>necessarily</u> mean that the marginal tax dollar is better spent on solar--though we shall suggest that, in fact, it is. How are conventional sources subsidized? In three ways, essentially. First, there is the direct subsidy to research and development, which has gone largely to the nuclear industry in recent years. Second, there are a variety of tax and regulatory policies, ranging from the oil depletion allowance to lower freight rates for virgin materials, that act indirectly to lower the prices of conventional energy sources. Third, there are the many environmental impacts of the fossil fuel cycle (and, potentially at least, of the nuclear fuel cycle) that have not been reflected in the costs and prices of energy commodities. Or, to put it differently, the processes of energy extraction, conversion and transportation have involved at the same time serious depletion of the common property resources--clean air, water, and scenic natural environments. And as these resources have been "free," though increasingly scarce, this represents an effective subsidy to the energy industry. Of course, other industries and economic activities have also benefited in this way, but perhaps not to the extent the energy industry has.

Now, given all of these direct and indirect subsidies to conventional energy production, it seems doubtful that more is called for. Indeed, it may be desirable, on economic efficiency grounds, to reduce some of the existing subsidies. This is almost certainly true for the environmental subsidy. The environment is also, and increasingly, a scarce resource, and ignoring this scarcity is not an efficient way to boost energy production.

But here is where solar energy comes in. One of the reasons, and we think a legitimate one, why solar energy is thought by many to be a "good thing" is precisely its low environmental impact. In a second-best situation, where polluting energy sources already receive an effective subsidy, it may be efficient to subsidize the relatively clean solar technology.

This is admittedly a qualified recommendation. The first-best policy would be to simply eliminate all of the environmental subsidy to the dirty technologies (incidentally improving the competitive position of solar). The resulting higher energy prices would also lead to a reduction in the quantity of energy demanded, or greater conservation. But if, for a variety of historical, institutional and political reasons not all of the environmental subsidy to conventional fuels can be eliminated, a reasonable second-best policy would be a countervailing subsidy to the clean alternatives, prominently solar.

A possible objection to the solar subsidy is that, by reducing the price of energy, it would in fact stimulate energy consumption. But this objection is not valid in any meaningful sense. An effective reduction in the price of solar would lead (in time) to a substitution of solar energy for other goods and services, chiefly those for which it can most closely substitute: other energy sources. The effect on consumption of exhaustible energy resources is unambiguously negative. Aggregate energy consumption could increase, but all of the increase would come from inexhaustible solar source. Of course, solar energy is not free; an increase in the quantity demanded would lead to an increase in the demand for complementary produced inputs, chiefly capital. But at a given level of macroeconomic activity, this is merely a question of who gets to use what inputs, a question which markets are ordinarily capable of resolving by allocation to maximize the value of production.

Another possible "second-best" argument for a subsidy to solar energy is that, as the most capital-intensive of the residential energy systems, it is disproportionately affected by capital market imperfections. That is, the capital costs of a solar space heating system are relatively high, and if potential users cannot easily borrow to meet these "front-end" costs, they will be kept out of the solar market, even if the system would pay off over its lifetime. We shall have more to say about front-end costs and capital market imperfections, and ways of overcoming them, in section IV below on alternative subsidy arrangments.

III. Another Argument for a Subsidy: The Value of Information

The arguments for a subsidy to solar energy advanced in the preceding section tend either to apply to domestic conventional sources as well (e.g., weaken oil cartel, reduce dependence on insecure foreign suppliers) or to be of the "second-best" variety (given the environmental subsidy to conventional sources, redress the balance with a subsidy to solar). We think these arguments have some validity, especially the latter. But we now propose another, which does not apply to conventional sources, and is a "first-best."

Suppose solar energy for hot water, hot water/space heating and hot water/space heating and cooling were competitive with the fossil fuel alternatives. Would we see widespread installation of solar collectors? In fact, the question is not hypothetical; in many parts of the co-ntry, and especially in California, solar space heating allegedly could be cost-competitive.[3/] To put the question more sharply, then, why don't we see sidespread installations? One reason is that existing structures were designed and built at a different set of relative prices, for fossil fuels and s-lar collectors, than that prevailing today. So even if solar were cheaper than fossil today, it would probably not be economical to scrap the existing structures or their heating plants. They must depreciate and be replaced over a period of years. Only if solar were very much cheaper than the existing machinery would it pay to make a replacement immediately.

But what about new buildings--homes, offices, and so on? Why are so few, and no large developments we are aware of, built with solar collectors?

3/ In California solar heating and cooling systems will be favorably cost-competitive with the systems they would replace if these systems use entirely electric, propane or oil as their energy source. For systems using natural gas at fuel costs of $2.00 per MMBTU solar systems will not be favorable based on present system costs and life expectancy.

Here there is no question of depreciation of an existing capital stock. Let us suggest an answer: uncertainty (lack of information) about the performance characteristics, importantly including expected lifetime, of the new equipment, and aversion to the risk associated. This is a problem with any new system. Information about performance comes with experience. And without the information, it is risky for any potential user to proceed. But we think this is a problem particularly for solar energy, becuase of the time pattern of returns to an investment in it. Certainly for an existing structure, but even for a new one, given the need for a conventional backup heating system, capital costs for solar are likely to be higher than for a purely conventional alternative. The saving of course comes in the form of lower fuel costs over the operating life of the equipment. For solar to be cheaper overall, then, the operating life cannot be too short. In fact, Bell (1977) calculates that a solar space heating unit with a purchase price of $10,000, operating in central Europe, will not "break even" over an estimated 20-year life. Yet there is not sufficient experience with the system, not a sufficient number of "system-years" of operation, to enable potential users to estimate with any confidence the expected life--and the reliability--of the collectors and related equipment they would install. In the absence of information about two key influences on profitability, the life of the equipment and maintenance costs over its (uncertain) lifetime, investment in it becomes risky. And if builders and homeowners are risk-averse, as we would normally expect them to be, the investment is less likely to be made.

The argument for government intervention here is that the missing information is what is known in economics as a "public good externality," which leads to the failure of private markets. An externality is a spill-over benefit or cost of one individual's action to another. Air pollution is a widely cited example of a negative externality, or external cost. The smoke from Mr. A's factory bothers Mr. B. It is also a public good--or perhaps we should say bad: what is consumed by one individual (Mr. B) does not reduce the amount available for consumption by another (Mr. C, D, etc.), and in fact it may not be possible to exclude from consumption, as with air pollution. In these circumstances, as is well known, private markets fail to allocate efficiently, and some form of collective action is necessary--though not always sufficient--to achieve efficiency.

How is information about the performance of solar collectors a public good externality? Each user's experience provides information (a benefit) to other potential users. This is the externality. And if the information is available to one, it is available to all. This is the public good. Yet obviously the individual user has no incentive to take account of the informational benefit he would provide to others, so that "too little" use--less than the amount that would be justified by its benefits--will be made of solar collectors. Carefully designed public policy <u>can</u> improve the efficiency of resource allocation if the costs of the policy are less than the benefits, in this case from increased use of solar energy.

There is one other point about the market failure here, which is relevant to the next section's discussion of subsidy schemes. Consider the following scenario, drawn from the recent theoretical analyses of Akerlof (1971) and Leland (1977). Suppose there is a wide quality range in the solar collector systems available on the market, but that, due to lack of experience, consumers do not have sufficient information to discriminate among them.

Then all brands will sell for the same price, which reflects average quality. But the high quality producers know who they are (even if consumers don't), and they are likely to have better opportunities in other sectors. They will therefore withdraw from the solar collector market, lowering the average quality, further lowering prices, leading to further withdrawals, and so on.

The implication for subsidy policy is that a subsidy must not simply encourage the proliferation of poor quality products. It ought to somehow also act to reduce the informational asymmetry between buyer and seller, or if this is not feasible, otherwise prevent quality deterioration from going too far.

IV. How to Subsidize Solar Energy

In the preceding sections we outlined some arguments for subsidizing solar energy that also have implications for the form the subsidy might take. There are, in fact, two goals, or targets, of a subsidy policy, which according to the well-known theorem of Tinbergen (1952) imply two subsidy instruments. Thus in section II we noted the difficulty caused by high front end costs and imperfect capital markets. What might be done to overcome this? One possible remedy, already enacted by the California legislature and proposed in the President's energy program, is a tax credit for part or all of the cost of installing a solar device. This cost can run from $2000 for a hot water heating system to $6000 and more for a hot water and space heating system.[4/] The California plan provides up to 55% of the cost as a tax credit up to a maximum credit of $3,000. In the proposed California plan, the taxpayer could continue to claim the credit in succeeding years, up to the maximum amount of $3,000. This plan has an income regressive quality since its present value is lower, the lower the taxpayer's income and therefore, the greater the number of years into the future he must wait to qualify for the full credit.

As an alternative to the tax credit plan that attacks the front end cost problem yet is not regressive, we propose a subsidized loan program. High front end costs are a problem because capital markets are not perfect. That

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4 See . . . .

is, even though the investment in a solar heating system might be a good one, i.e., yield a positive present value, the person contemplating it may not be able to borrow the full amount--say $6000--at a flat (market) rate of interest. This is quite likely in the case of an uncertain venture like solar space heating coupled with the low collateral typical of poor families. To make the investment possible, then, the government could remedy the capital market imperfection by providing a fund for solar loans at a flat rate of interest. This rate need not be below the market rate for similar loans, where they are in fact made by private lenders. But the borrower should be able to borrow all he wants, up to the cost of the solar investment.

Such a scheme has at least two advantages over the tax credit. First, it is not regressive. A poor or middle income family would receive the same benefit as a rich one installing the same device. Second, it attacks the market imperfection directly, by simply supplementing the private loan market. If the imperfect private loan market (coupled with the relative capital intensity of solar energy) were the only distortion in the energy market, there would be no reason for any collective action beyond a loan program like the one proposed. In particular, there would be no reason for collective assumption of part or all of the cost of installing a solar heating system, as under the tax credit plan. But we have argued earlier that there are at least a couple of additional market failures that discriminate against solar--the environmental costs of alternative energy systems, and the public good information externality generated by solar users. Both of these argue in favor of an offsetting subsidy to solar. But a non-regressive loan program could provide this just as well as a tax credit. Part of the loan could be forgiven (perhaps a larger part for a poor family, to make the plan progressive) or, what is the same thing, the interest rate could be reduced.

We said at the beginning of this section that there were two targets of subsidy policy, and therefore presumably two appropriate instruments. One target, elimination of the barrier raised by high front end costs and imperfect capital markets, might be dealt with either by means of a tax credit, as provided in California and proposed for the nation as a whole, or a loan subsidy, as we have proposed. The other goal of a solar subsidy is to eliminate or at least reduce the barrier to investment raised by the uncertainty about the durability and other performance characteristics of the new and largely untried system, as discussed in section III. To accomplish this latter goal we propose another extension of the market: a government-backed service warranty for buyers.

The idea of the warranty is that the buyer would receive it along with his solar device. If, at any time during the life of the warranty repairs or replacements were needed, the buyer would have them made and present the government with the bill for reimbursement. The warranty would shift some of the cost and the risk attached to the solar investment from the individual buyer to the government, or all taxpayers. What we are proposing, then, is simply an extension of warranty contracts such as are offered by manufacturers or sellers for many existing appliances--oil burners, dishwashers, and so on--to solar heating systems. We might ask why private sellers don't in fact generally offer warranties for solar devices. The answer is presumably, for the same reason that buyers are reluctant to buy: the very substantial risk involved.

Variations in the scheme are possible. At least two deserve mention. First, and perhaps most important from the point of view of a government agency trying to control expenditures, the warranty program could pay for itself. Buyers of solar heating systems could be charged for the warranty. If the charge reflected all of the expected service costs, there would be no cost to the government other than administration. The buyers are still better off than with no warranty, however, because they are still insured against large (larger than average) losses. The risk has been shifted from the individual buyer not to all taxpayers, as when the warranty is "free", but to all buyers. And of course intermediate positions are possible, with the price of the warranty reflecting only a portion of the expected service costs. It must be noted, though, that imposing some or all of the costs of the warranty on buyers would reduce the expected increase in demand for the solar products.

The second variation also has to do with risk sharing. The warranty as just noted, shifts the risk of part or system failure from the individual buyer. The question might be raised, what incentive does he then have to avoid abuse of the equipment? To guard against this "moral hazard" as it is known in the insurance literature, some degree of co-insurance could be desirable. For example, insurance against theft often applies only to losses above a specified deductible amount. And medical insurance often covers only a portion--though a large one, around 80%--of certain items. The idea seems to be that a small share in the risk gives the buyer an incentive not to be careless with the insured object. Of course, the price of the insurance policy or in this case the service warranty must be correspondingly reduced.

There is one other theoretical issue that must be faced before we move on to cost out the suggested subsidies, in particular the warranty. Recall, from section III's discussion of the implications of uncertainty about the performance of solar heating systems, that not only will too small a quantity be produced and sold, but there will be a tendency to a downward spiral in quality. The subsidies we have been discussing would, by increasing demand, increase the sales of solar devices. But how can a tolerable quality level be attained, or maintained?

This suggests a third goal or target of subsidy policy, namely, maintain a desired quality of product, which in turn calls for a third instrument. The obvious one is a quality standard, as employed for many other products or services, but there is a problem in this case. How can product characteristics be specified without the information about performance that leads to the market failure in the first place? Or to put the matter another way, there are two potentially serious costs of mandating product specifications: the direct costs, importantly including the needed research by the standard-setting agency, and the indirect costs of inhibiting innovation by producers in a new field.

Once again we propose relying on market forces, or better, corrected market forces. Instead of trying to set standards in a state of ignorance, why not penalize the poor quality producers by assessing them part of the repair costs under the warranty? This puts the problem in the context of financing, or cost sharing, of our preferred subsidy instrument, the service warranty. To keep the market from being flooded with poor quality solar products (some of them induced by the subsidy), let the producers bear some of the cost and the risk of product failure. This gives them an incentive to maintain or improve quality. For example, the producer might pay a fraction of warranty costs that depends on his repair record. The higher the frequency of repairs of his product, relative to the average, the higher the fraction of warranty costs he pays. In the beginning, with no repair history, all producers would start out equal, perhaps paying none of the costs, the government and to a small extent buyers absorbing them. Over time, however, the costs of the poor quality producers would rise, perhaps ultimately to a level of 100% of the warranty.

There is just one difficulty with this scheme, which suggests that it needs to be used with care. The penalty for poor quality will raise the costs of producers above what they would have been without it, either because they are paying for (part of) the warranty or because they are using better materials, design features, and so on, in their products. Other things equal, the increase in producer costs will lead to a decrease in output. Of course, other things aren't equal. Specifically, we assume consumer demand has increased, due to the subsidy. But the point is that the shift in costs and supply will work in the opposite direction in its effect on output. And the main objective of any subsidy program is after all to stimulate output. So producer cost sharing, even if related to quality in the right way, needs to be used with care. Specifically, if demand for the product is very elastic (a small price change is associated with a large quantity change), the cost increase will have a serious impact on output.

Talk about cost sharing leads us to the main business of the next section: estimating the costs of a warranty. Of course we are also concerned about the costs of a tax credit or subsidized loan program, but these are relatively straightforward: for the California tax credit, for example, 55% of purchase and installation costs up to a maximum of $3000, per device. To estimate the costs of a warranty on the same device, however, we must know something about the probability distribution of component failures and their associated costs, and not just in any short period like a year but over the entire life of the warranty. In practice we shall work with just the first moment of the distribution, its mean or average. That is, we look at expected repair costs over each of, say, 10 years of a warranty.

It is important to bear in mind, though, that in talking about the costs of a warranty we are talking about disbursements, or transfers, from a government warranty fund to individual solar users. These are not real resource costs, as the repairs or replacements are incurred with or without a government-backed warranty program. The only real costs attributable to the program are its administrative costs--which as we have warned could be substantial if the government were to get into the business of setting and enforcing standards. Certainly government expenditures, even if only transfers, are of concern to policy makers, and that is why we present some estimates in the next section. But recall also that, by charging a price to buyers for the warranty or imposing a share of the costs on producers, it is possible for the government to make the program--with some output slippage--as nearly self-financing as desired.

V. Estimating A Solar Warranty Cost

To estimate these costs we have used the basic failure analysis developed by the TRW Systems Group for the National Science Foundation.[5] They have analyzed all the components in typical hot water, hot water/space heating and hot water/space heating and cooling systems and have given the expected annual failure rate for each individual system component. Table 1. below is adapted from the TRW report for their hot water system and their hot water/space heating system diagrammed in Figures 1 and 2. For their example systems we would predict an average of 0.72 failures per year for the hot water system and 2.05 failures for the hot water space heating systems.

TABLE 1. (Adapted from TRW Report, Ref. 5)

Frequency of Repair Rank	Component Element	No. in Hot Water System	No. in Hot Water Space Heating	Component Failure Rate
1	3-way solenoid valve	1	4	0.100
2	2-way solenoid valve	1	3	0.100
3	Elec. Sensors	4	11	0.050
4	Elec. Controllers	2	5	0.067
5	Circulating Pumps	1	3	0.067
6	Check Valves	0	1	0.043
7	Solar Collector	1	1	0.100
8	Aux. Gas Fired Heater	0	1	0.083
9	Heating Coil	0	1	0.020
10	Pre Heat Coil	0	1	0.020
11	Storage Tank	1	1	0.018

Total Hot Water System Failures - 0.72 per year

Total Hot Water/Space Heating System Failures - 2.05 per year

(Ratio $.72/2.05 = .35$)

[5] Solar Heating and Cooling of Buildings, NSF/RA/H-74-022A, (May 31, 1974)

The prediction for the hot water/space heating system is corroborated by discussions with two firms involved in designing, building, and servicing solar systems. [6] Their maintenance experience resulting from approximately 10 years of operation as shown in Table 2. for a $6,000 hot water/space heating system.

Year 1	2 to 3 service calls at $70/per call	Cost $140 to $210
Years 2 - 5	1 to 1.5 service calls at $70/per call	$70 to $105/year
Years 6 - 10	1.5 to 1.7 service calls at $70/per call	$105 to $120/year

Table 2. Repair Estimates for hot water/space heating system from Reference 6.

For the above example the high side numbers for service calls agree quite closely with the predicted values in Table 1.

Although we have not obtained actual service frequency for hot water systems alone, we might expect on the basis of the good agreement in the more complex hot water/space heating system predictions that the frequency of repairs for the hot water systems and their repair costs will be approximately as predicted, i.e., 1/3 of that for the combined hot water/space heating system. Using the figure of .72 repairs per year at $70 per repair then gives us an average repair cost for the hot water system of $50 per year as compared to approximately $140 per year for the hot water/space heating system.

[6] Piper Hydro and Truman Temple Companies of Southern California.

With these unit values we can compare the tax credit costs with the warranty costs for a typical solar system. As a numerical example, we consider the case of a hot water system alone and make cost comparisons with the tax credit using the present value of the various costs. The present value is one of several accounting precedures which can be applied to the comparison. Since monies or assets that do not have to be paid out until a given year can be invested to obtain earnings up to that year, the present value accounting method is indeed a valid procedure. This is true even in the face of an "across the board" inflation where the costs of all goods and services rise uniformly since the value of the held asset is also increasing along with the general inflation rate. On the other hand, the cost of repairs in fixed dollars could decrease within a competitive expanding service industry.

To carry the example further, we consider the purchase of a $2,000 hot water system by a consumer with a $450 state tax liability. If a 55% tax credit is to be allowed ($1100) then it would be paid over a three year period. With an assumed discount rate of 8%, this cost has a present value of $1038. This cost may be compared to a fixed period warranty cost which for example could be 10 years. Based on the average repair cost of $50 per year, this cost would have a present value of $362. Normally, the first year of service is included in the price of the system so that the 10 year budget cost to the government should be reduced by $50 to an amount of $312 which is then an additional cost of 15.6% over the initial cost of $2000. This number would be larger if we assumed that the rate of increase in repair costs were greater than the general inflationary rise of all goods and services and would be smaller if the costs of repair were to decrease in fixed dollars.

The costs for 5 through 10 year warranties based as above on their present value with an 8% discount rate are shown in Table 3. Warranty costs for the hot water/space heating system can be obtained from Table 3 by multifpying by the failure ratio of 2.85.

5 year warranty	Cost $166 (8.3%)
6 year warranty	Cost $200 (10.0%)
7 year warranty	Cost $231 (11.5%)
8 year warranty	Cost $266 (13.3%)
9 year warranty	Cost $289 (14.5%)
10 year warranty	Cost $312 (15.6%)

Table 3. Present Value Service Warranty Cost Based on 8% Discount Rate (Hot Water System, $50/year average repair cost.)

We note that since repairs may occur more predominantly in the older systems the average present values above could be somewhat conservative.

Although these cost estimates are crude, they indicate that for approximately 10% to 15% of initial costs a comprehensive service warranty system could be emplaced (this does not include the administrative costs). In view of the elimination of the service uncertainties to both producer and consumer and in view of the potential impetus to promote a new industry, the service warranty concept deserves careful consideration as an important tool to accelerate market penetration of solar systems.

The average value of $50 per year for the hot water system service charge chosen in the above example as used only for illustrative purposes. The actual value may be different depending on the particular system, location, use, and other variables.

Table 4 shows the discounted values of an average warranty cost for each $1 per year for a few discount rates and warranty lifetimes. If the first year is to be paid by the manufacturer then 1.00 should be subtracted from each number in Table 4. For example, suppose the discount rate is 12% and the warranty is to be over an 8 year period with an average annual cost of $58, and the first year cost to be born by the manufacturer. The total warranty cost, not including the first year is then obtained by multiplying $58 x 4.46 = $259.

TABLE 4

Discount Rate	5 yrs	6	7	8	9	10
8%	4.31	4.99	5.62	6.21	6.75	7.25
9%	4.24	4.89	5.49	6.03	6.53	7.00
10%	4.17	4.79	5.36	5.87	6.33	6.76
12%	4.04	4.60	5.11	5.56	5.97	6.33

Table 4. Discounted value of $1 added each year for N years.

We thank W. Klein of Energy and Resources for the useful information provided in Table 2, and for helpful discussions.

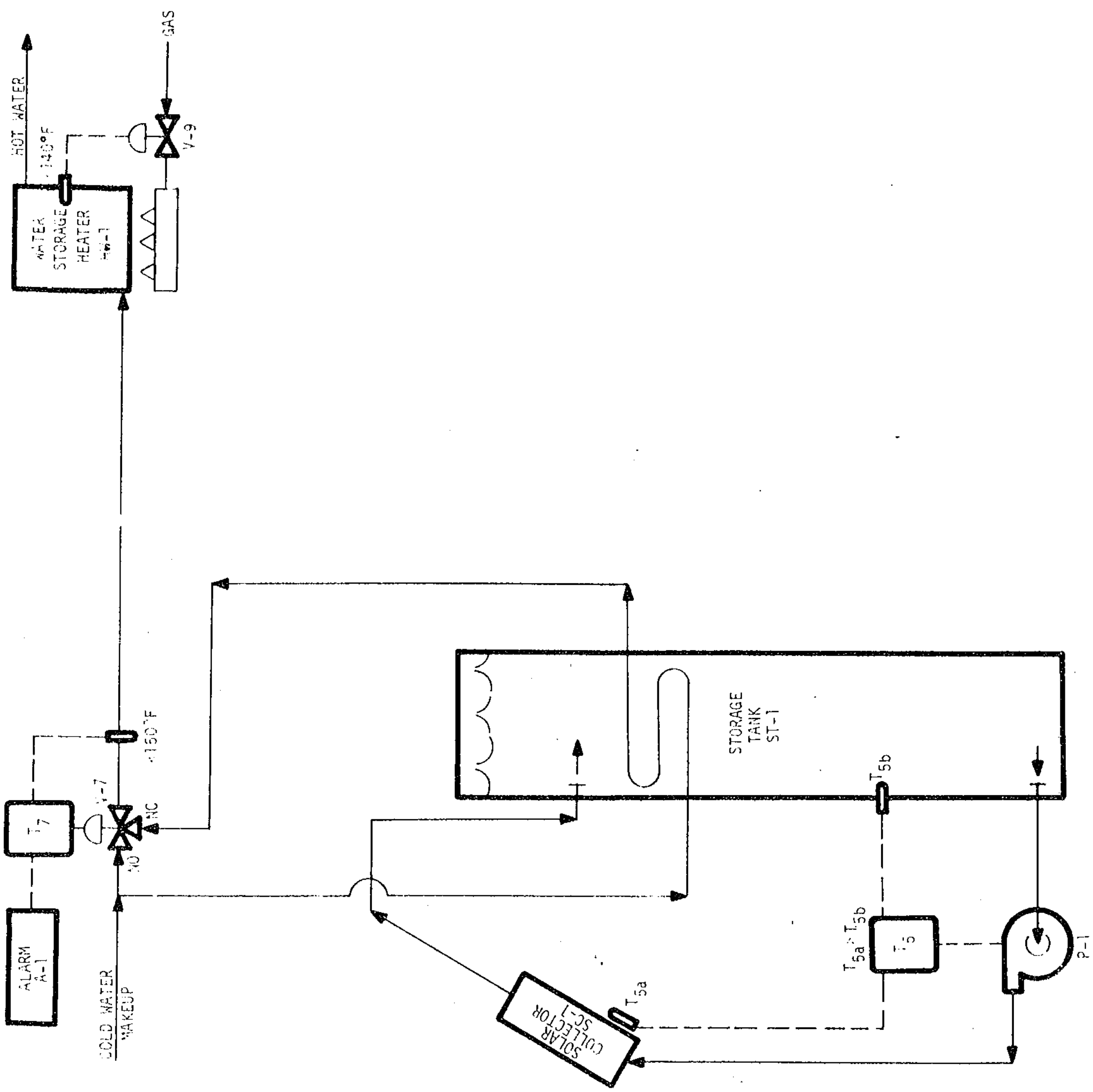

Figure 1 Reference Hot Water System

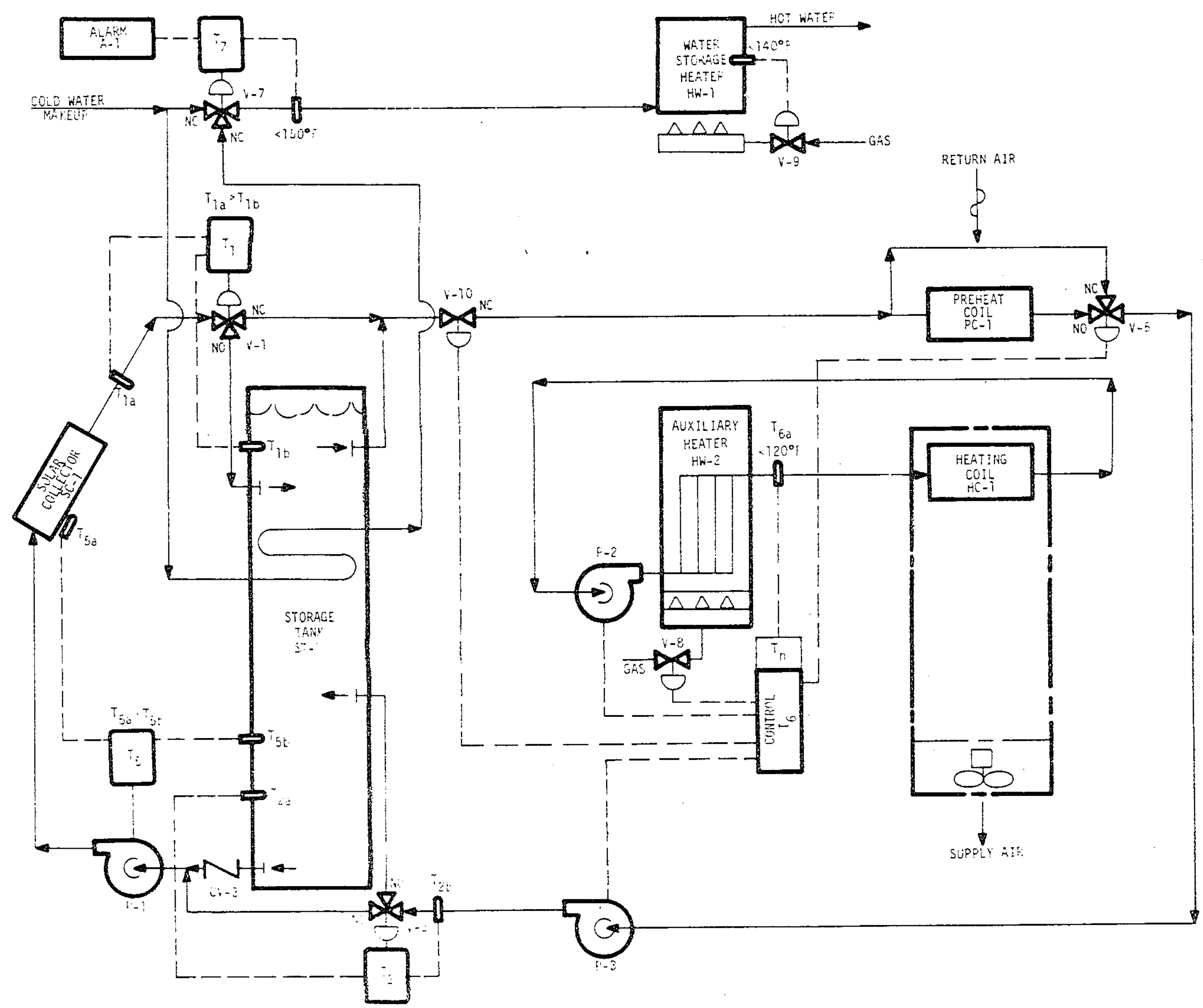

Figure 2 Reference Hot Water & Space Heating System

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This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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