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THE ROLE OF THE GOVERNMENT IN THE DEVELOPMENT OF SOLAR ENERGY

MICHAEL D. YOKELL

PRESENTED TO THE ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

ANNUAL MEETING

HOUSTON, TEXAS

JANUARY 4, 1979

Solar Energy Research Institute

1536 Cole Boulevard
Golden, Colorado 80401

A Division of Midwest Research Institute

Prepared for the
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Prepared by Michael D. Yokell* for the
Annual Meeting of the American Association for
the Advancement of Science, Houston, Texas
January 4, 1979

ABSTRACT

This paper discusses the economic rationale for a federal solar energy subsidy program, the type of program required, and methods for determining the proper funding level for each program. An introduction offers a brief description of solar technologies. A summary of the current federal solar subsidy program is also provided. Nonsubsidy programs, such as the promulgation of federal standards for solar manufacturers, are not discussed.

*Senior Economist, Solar Energy Research Institute, Golden, Colorado. The views expressed here are the author's and do not necessarily represent those of the Solar Energy Research Institute, its operator, the Midwest Research Institute, Inc., or the U. S. Department of Energy. Helpful comments have been received from Dennis Costello, Sam Flaim, Bert Mason, Marty Murphy, and Lewis Perelman. Joyce Barrett provided valuable editorial assistance. An earlier, abridged version of this paper was presented to the American Economic Association annual meeting held in Chicago, Illinois, August 30, 1978.

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SECTION 1.0

INTRODUCTION

The two most important types of policy applicable to solar energy are: (1) research, development, and demonstration programs; and (2) incentives policy which encourages or discourages production and consumption of solar energy. Both types of policy are addressed in this paper. The latter is the larger taxonomic category, as it includes tax and subsidy policy and gas and electric utility pricing. Solar issues not considered here include legal topics such as establishing the right not to be shaded by an adjacent property, the imposition of federal standards and codes for the solar industries, antitrust issues, and many others.

In Section 2.0, the question of whether the federal government should subsidize solar energy is addressed. In Section 3.0, a brief review of current federal subsidy programs for solar energy is presented. This provides the basis for Section 4.0, which presents the policy options for subsidizing solar energy. Section 5.0 discusses the proper balance among these options. Section 6.0 is a brief conclusion.

For readers unfamiliar with the solar technologies, a very brief review is in order. This review is based on Witwer et al. (1978). There are generally considered to be seven distinct solar technologies: photovoltaics (PV), solar thermal power, wind systems, solar heating and cooling of buildings (SHACOB), agricultural and industrial process heat (AIPH), biomass, and ocean thermal energy conversion (OTEC).* Some of these "technologies" actually embody more than one distinct technology.

Photovoltaic devices convert light directly to electricity. The most common current technology utilizes silicon cells without any device to focus sunlight on the cells. A variety of other materials are being utilized, and devices that concentrate sunlight onto small photovoltaic cells are under development. In large quantities photovoltaic cells can now be bought for about $15/peak watt (1977 dollars). This translates to delivered electricity costing about $1 to $2 per kWh (Kelley, 1978). In comparison, the average price of electricity in the United States in 1976 was 2.89 cents (Edison, 1976, p. 53). The 1976 production of silicon cells was over 350 kW-pk and 1977 production was over 750 kW-pk.

Solar thermal power systems concentrate sunlight at a point or along a line and use the heat to produce steam, which is then converted to rotating mechanical power or electricity. A 10 MW-central receiver "power tower" demonstration plant is scheduled for completion by the Department of Energy (DOE) in 1980. Delivered electricity costs from commercial-scale plants are difficult to predict at this stage of development. Because of the high cost of energy storage, the power tower will probably be used at first primarily in

*An eighth technology, solar powered satellite stations, is the least developed of the solar technologies and will not be discussed here.

a "fuel saver" mode. Little existing generating capacity would be displayed by power towers operated in this system configuration.

Wind systems are an old technology utilized for milling grain and more recently for the direct pumping of water. Although water pumping is still a potentially important use of wind power, recent research and development has focused on conversion of wind power to electricity. Wind machines come in many sizes and shapes. Generically, they can be divided into horizontal- and vertical-axis machines. Both designs are currently under development. Economical sizes range from about 15 kW to 3 MW.

A solar heating and cooling system consists of a radiant energy collection system, an energy storage system, an energy transfer system, and an exchange system. For cooling an additional system is required. There are many variations of solar heating systems: some concentrate sunlight, others do not; some track the sun as it moves across the sky in either one or two dimensions, others do not. Some solar heating systems use air as a heat transfer medium, others use any of several liquids. Systems also vary in the medium they use for heat storage. From an economic point of view, the distinguishing feature of SHACOB systems is that they have very low fuel and operating maintenance costs and high initial costs. In some U.S. climates, solar water and space heating is now cheaper on a life-cycle basis than electric resistance heating. Water heating is cheaper than space heating because capital costs are spread out over year-round use.

Solar heating for agricultural and industrial process applications utilizes technology similar to that in the SHACOB sector. The distinguishing features are industrial users' capability to deal with more complex systems and year-round use leading to high capacity factors.

The use of biomass for energy conversion involves two distinct phases: production of biomass (or collection of existing unutilized biomass) and conversion to suitable fuel. Solid, liquid, and gaseous fuels are all technologically if not commercially viable. Biomass can be burned directly in utility boilers to produce electricity, it can be fermented to produce liquid fuels, or it can be gasified to produce low or medium Btu gas.

Ocean Thermal Energy Conversion (OTEC) systems utilize the temperature difference between warm surface ocean waters and deeper cooler waters to produce electricity. Two generic systems are currently under study: open cycle systems in which seawater is evaporated rapidly and drives a steam turbine, and closed cycle systems in which seawater heats a working fluid which is evaporated and drives a turbine. Although there is an enormous amount of energy available in thermal gradients, modern OTEC systems are still in the conceptual stage.

SECTION 2.0

SHOULD THE FEDERAL GOVERNMENT SUBSIDIZE SOLAR ENERGY?

The federal government should subsidize solar energy for both "first-best" and "second-best" reasons. These terms are defined by Western economists with respect to a normative standard of an idealized, "perfect competitive" economy (Mishan, 1959, p. 202). First-best policies are those which could increase social welfare if the economy were perfectly competitive. Second-best policies are those which are designed to increase social welfare in an imperfectly competitive economy.

First-best reasons include: (1) Innovation often involves a public good externality because the social returns from innovation cannot be entirely captured by an innovator; (2) Investors in the innovation process are usually risk averse when investing in new technologies. By pooling the risk over a far larger number of individuals, society should willingly support a higher level of investment in risky innovations than private firms or individuals would; (3) Private purchasers of new technology are averse to risk of product failure, improper installation, etc. The private willingness to purchase an innovative product would be raised to optimal levels if risk could be pooled with other members of society; (4) Capital market imperfections can prevent a purchaser from taking advantage of potential life-cycle savings offered by capital-intensive solar technologies.

Second-best reasons for subsidizing solar energy include: (1) Large, partially unjustified subsidies to conventional energy technologies currently cause them to be overused relative to solar energy technologies; (2) Average pricing arrangements for petroleum, natural gas, and electricity cause them to be overused relative to marginally priced solar energy technologies; (3) Large, partially unpriced environmental external diseconomies result from the production and consumption of energy from conventional sources. Conventional energy sources are overused relative to energy from solar technologies, which generally involve significantly less environmental impact. For each second-best problem, there is a first-best remedy applicable, as noted below. Unfortunately, these remedies do not appear to be politically viable at present. Generally speaking, this is because first best solutions involve removing existing subsidies that have developed powerful constituencies. Offsetting subsidies are politically viable because they too have or are developing constituencies.

Each of these reasons for subsidizing solar energy is discussed briefly.

An innovation in production is not merely the invention of a new product or process but requires that the product or process actively begin to penetrate the appropriate market. Innovations <u>per se</u> are thus not patentable. Specific devices or production technologies are patentable, but patent laws do not generally afford great protection to the inventor in a field of technical ferment, both because generic ideas are not patentable and because relatively minor technical changes on a basic technological theme often result in the award of new patents. Thus, a firm which pioneers an innovation may expect to share the profits from the innovation with other firms in the same field. In fact, there is some evidence that "fast second" firms entering a new market can capture more of the profits from an innovation than the innovator. Moreover, an innovation can result in significant benefits to consumers, which they and not the innovator capture. Thus, on both the production and consumption side, an innovator cannot necessarily capture the full social benefits* of his innovation and is, therefore, quite unlikely to invest a socially optimal amount in its development.

Even if an innovator were assured of capturing the full social benefits available from a particular innovation, there is no advance assurance that these will be positive. The entire process of innovation, which includes bringing an invention to market, can be extremely costly, and the net social benefits of many innovations are assuredly negative. The private investor, even a large one, is often risk-averse and requires higher than average expected returns as compensation. Thus innovation does not take place unless high returns are foreseen by the investor. Because the loss from any one successful innovation is a much smaller fraction of society's assets than it is of even the largest firms, society may well be significantly less risk averse to this loss than a private firm. Again, less than socially optimal investments are made in innovation. By subsidizing the process, the federal government can raise the level of investment in innovation to socially appropriate levels. Although in theory it would be possible to rely on an insurance market to protect firms against at least partial loss attendant upon unsuccessful innovation, no such market has ever developed.

A similar phenomenon can be seen on the consumer side of the market. Any individual innovative product is likely to provide only a relatively small increase in consumer surplus for the typical consumer. Yet if the product fails, the attendant loss of consumer surplus may be large, relative to the consumer's total resources. Even if the expected returns are positive, the typical consumer will be risk averse and consume fewer innovative products than he would if the loss from possible product failure were small. This reduction in perceived risk can be achieved by spreading actual losses over many consumers through a risk pooling mechanism such as insurance. The increase in social welfare attendant upon product failure risk pooling is sufficient justification for this type of arrangement, but it does not necessarily require federal subsidies. Private insurance markets, usually in the form of product service contracts, often provide the essential risk pooling. However, before an actuarial record has been developed (and thus when uncertainty is great) private insurers may be unwilling to enter the insurance market. Therefore, if solar technologies provide positive net social benefits, temporary federal support for solar equipment warranties is desirable.

Solar technologies (with the exception of biomass) do not require much fuel. As a fraction of life-cycle costs, "up-front" costs are higher for solar technologies than for most other energy technologies. For the end user, financing arrangements are, therefore, more crucial for solar than for other energy technologies. Consider a solar technology whose present discounted costs are lower than those of a competing conventional system (i.e., the solar

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*Mansfield (1977) has attempted to measure the difference between social and private benefits from a variety of innovations.

system is "economic" according to the conventional definition). In today's residential loan market, the solar user may have great difficulty financing the additional costs of a solar system. In retrofit applications, loans are often unavailable, or available at home improvement rather than lower mortgage interest rates. For both the business and residential user, the problem is the lender's use of cash flow rather than economic criteria for evaluating loan proposals. Economically feasible solar systems may have long discounted payback times exceeding the length of typical business loans. If the user has a cash flow problem, which he often does, a solar system becomes an unattractive option.

In both the residential and business cases, federal intervention is called for to improve the functioning of the capital market and ensure that lending institutions encourage rather than discourage economically feasible solar energy systems.

Before discussing second-best reasons for subsidizing solar energy, it might be useful to ask whether there is anything outstandingly different about innovations in solar energy from innovations in other technologies. The answer is no. Thus for the first subsidy argument to be valid, the "traditional" view that private firms invest a less than socially optimal amount in innovative activity must hold (but see Hirschliefer, and Kamien and Schwartz). Second- best arguments are more directly concerned with solar energy technologies.

A recent report by Cone et al. (1978) catalogues federal subsidies to energy production and estimates their magnitude. The total subsidy was estimated to range between 123.6 and 133.7 billion undiscounted dollars since 1918. Some of these subsidies can be regarded as first best attempts to improve the functioning of the private energy market, but many of them have little justification other than political expediency. Many examples come to mind,* particularly from the petroleum industry, which received 60% of the subsidies (not including those to natural gas). Most of these subsidies result in a market price below that which would exist under perfect competition. Flaim (1977) has shown this for tax subsidies to the petroleum industry. In this situation, solar energy systems are competing against artifically low priced conventional energy systems. A first-best solution is obviously to remove the unjustified portion of subsidies from conventional energy sources. This currently appears politically impossible, although progress has been made by eliminating the oil depletion allowance. A second-best alternative may be to provide federal subsidies for solar systems to compensate for subsidies to conventional fuels and thus prevent distortion in interfuel competition. While there is no general theoretical proof that an intervention of this type results in a net increase in social welfare,** it is likely to do so in this case.

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*Tax subsidies for petroleum include immediate expensing for tax purposes of intangible drilling expenses which are economically capital in nature and tax credits for "foreign taxes" which are economically in the nature of royalties.

**See Lipsey and Lancaster.

In cases where direct solar end-use competes with electricity or natural gas distributed by utilities, a marginally priced good is competing with an average priced good. A similar situation occurs in the market for refined petroleum products under the "entitlements" program. Residential solar heating and hot water systems competing with electric resistance heating systems (now accounting for about 50% of the new market) are a case in point. The end user sees the true marginal cost of the solar system but only an average price for the fuel component of the electric resistance heating system. A first-best solution to this price distortion would be to require utilities to utilize marginal cost pricing and simultaneously tax away any windfall profits that the utility would capture from this pricing mechanism. Since marginal cost pricing has been implemented in only a handful of the nation's utilities, a second-best solution seems to be called for, at least for the time being.

Conventional energy sources are directly responsible for significant external diseconomies. While there has been no definitive work quantifying in dollars the health, property, crop, etc., damages due directly and indirectly* to conventional energy related pollution, very rough calculations indicate they are large.**

Solar energy systems generally have little if any direct pollution associated with them, and their substitution for 10% of conventional energy demand would accordingly provide at least $1.5 billion in health-related social benefits.*** Because pollution is generally unpriced, pollution-intensive products are underpriced and overused. According to the well-known argument,**** a first-best solution to this problem would be the provision of optimal taxes per unit of pollution, rebated to the public on a per capita

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*The term "indirectly" refers to damages caused in the process of manufacturing the inputs to the conventional systems, the inputs to these inputs, etc.

**Lave and Seskin (1977) estimate that a 58% abatement of particulates and an 88% abatement of sulfur oxides would result in a reduction in health damages of 16.1 billion 1973 dollars or 21.5 billion 1977 dollars (p. 225) from stationary sources alone. Of emissions from stationary combustion systems, electric generation alone represents 63.8% of the particulates and 73.5% of the sulfur oxides; other energy-related sources also exist. Thus, very roughly, 3/4 of the potential reductions in particulate and sulfur oxide damages (or about $15 billion) are directly energy related (U. S. Dept. of Energy, 1978). Moreover, the Lave and Seskin estimates probably seriously understate pollution damages.

***Indirect environmental benefits and costs of solar systems also need to be quantified. Research in this area is currently underway. See Yokell (1978 and 1979).

****See Baumol and Oates (1975) Chapter 3.

basis. Under this solution, pollution-intensive energy systems would be automatically penalized compared to relatively pollution-free systems. Since pollution charges have made little political headway in the United States, a second-best solution would be to subsidize low polluting industries which compete in the same market with pollution-intensive industries.

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SECTION 3.0

THE CURRENT FEDERAL SOLAR PROGRAM*

In this section five federal programs for solar energy are discussed: (1) research and development programs; (2) demonstration programs; (3) federal installation programs; (4) purchase programs; and (5) federal tax credits.

It is currently the policy of the Department of Energy (DOE) to sponsor significant research and development in the various solar technologies. Figure 1, from Perelman et al. (1978) presents a convenient summary of the budget allocations for solar energy, both relative to other technologies and among solar technologies. The entire Department of Energy solar budget, $411 million in FY78, is only 4% of the total, but this percentage has been growing rapidly.

DOE's solar functions are distributed between the Assistant Secretaries for Conservation and Solar Applications (CS) and Energy Technology (ET) on the basis of technology development status. Solar technologies which are considered mid- to long-term energy supply strategies (solar thermal, photovoltaics, wind energy, and ocean thermal) are located in ET, and presently demonstrable technologies (solar heating and cooling, plus agricultural and industrial process heat) are situated in CS. Thus, most federal solar research and development is located in ET.

Among the principal current and planned ET programs are: technology development in support of the Solar Heating and Cooling Demonstration Program; construction of a 10 MW_e central receiver power plant to test, demonstrate, and produce solar-generated electricity; major procurement of photovoltaic systems and continued research into system cost reduction; continued development in both small wind machines and large-scale, multiunit wind systems; and conversion of the Hughes Mining Barge into an ocean thermal energy conversion test facility. ET is the source of funds for the Solar Energy Research Institute.

The federal government sponsors a program for solar heating and cooling demonstrations. The commercial and industrial portions of this program are administered by the Department of Energy, while the residential portion is jointly administered with the Department of Housing and Urban Development.

In addition to the demonstration program, there is an active federal program to install solar systems in federally owned buildings. This program is coordinated by the Department of Defense (DOD). DOD also provides a major share of the market for solar electricity.

Numerous other federal entities, from executive departments to national laboratories, have small solar programs.

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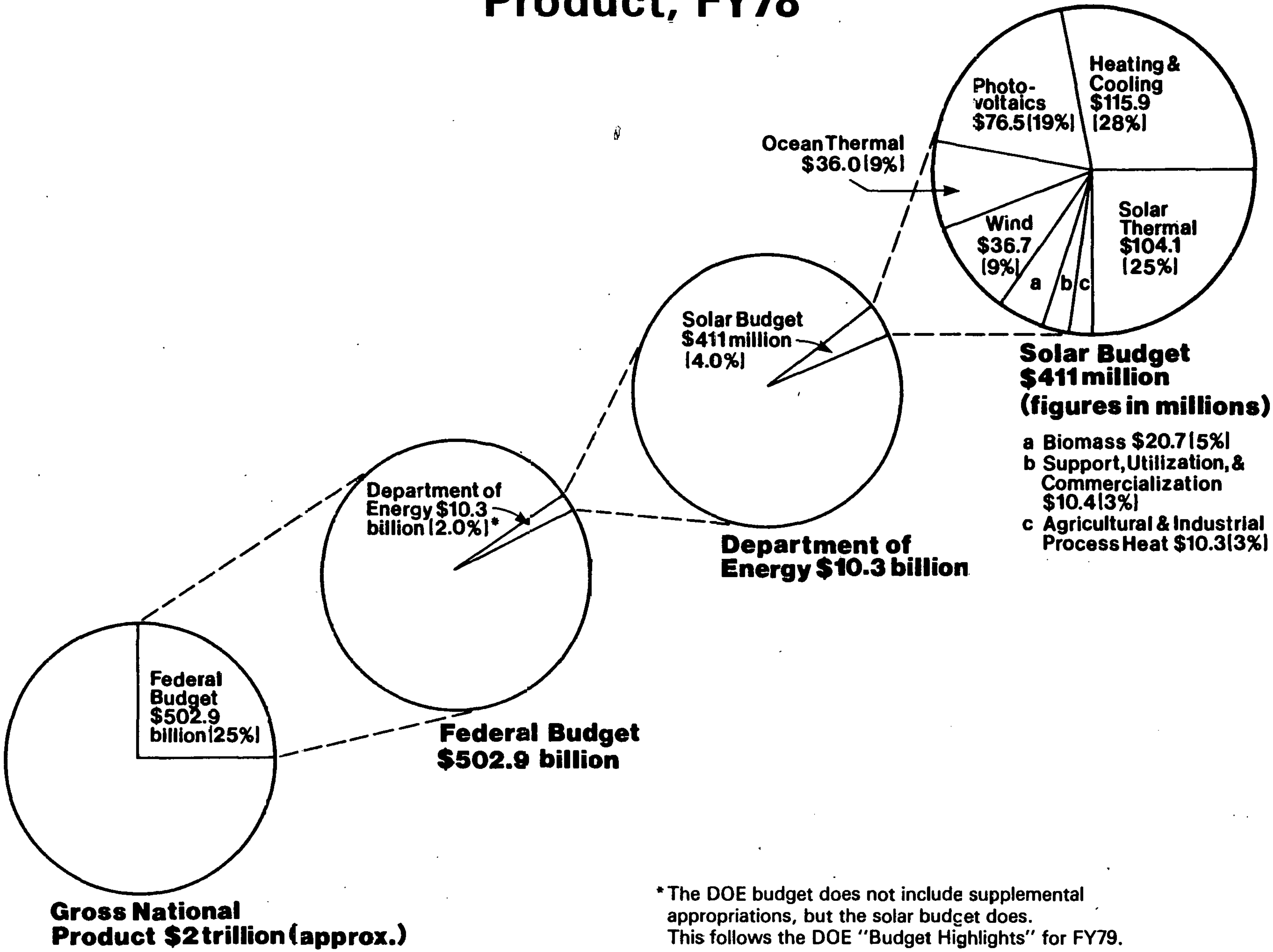
*This section relies heavily on Perelman et al. (1978).

Solar Budget in Relation to Energy and Federal Budgets and to Gross National Product, FY78



*The DOE budget does not include supplemental appropriations, but the solar budget does. This follows the DOE "Budget Highlights" for FY79.

FIGURE 1

The Energy Tax Act of 1978, passed by the 95th Congress and signed by President Carter, provides for a homeowner tax credit of 30% of the first $2,000.00 and 20% of the next $8,000.00 expenditure on a solar or wind energy system for a maximum of $2,200.00.

Other applicable federal assistance is that currently available to any business establishment through the tax system, such as accelerated depreciation, investment tax credits, etc. Since solar energy systems require large outlays, these credits can be substantial. They have to be balanced, however, against the absence of any fuel expense which, for conventional energy systems, can be written off directly against income. A cursory examination by Witholder and Yokell (1978) of the relative impacts of all federal tax laws on conventional and solar systems found no "discrimination" against solar systems, as some solar proponents had claimed. Solar energy is not favored, however, as might be indicated by an economically optimal social policy. Several states are considering or have passed tax incentives. The most generous is California's, which allows 55% of the cost of a single-family residential solar system to be deducted from state income tax liabilities, to a limit of $3,000.

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SECTION 4.0

FEDERAL SUBSIDIES FOR SOLAR ENERGY

This section presents the policy instruments for subsidizing solar energy. A "policy instrument" can be defined as a generic program. A "program" is any specific instrument whose funding level may be varied independently. This section does not discuss specific solar programs; in the analysis of any specific program its administrative costs and the costs of any side effects must be weighed carefully against the main benefits of the program.

Federal subsidies that would be justified under conventional economic theory for any of the first- or second-best reasons discussed in Section 2.0 are not necessarily those that would be suitable for meeting any specified level of market penetration. Much of the literature on federal subsidies for solar energy has attempted to estimate the required type and level of subsidies to meet a specified level of solar market penetration. In the following discussion it is important not to confuse this issue with the "optimal" federal subsidy, which is discussed here.

In Table 4-1, the economic problems associated with solar energy are listed on the vertical axis and proposed solutions are listed on the horizontal axis. An "X" indicates that a proposed solution is capable of affecting a problem. The following discussion of proposed solutions refers to the table.

Solution A, direct grants to end-users, compensates for the underpricing of conventional sources of energy and thus is a second-best corrective action. This solution also corrects for the high first-cost barrier and thus compensates for the capital market imperfection, which lowers or eliminates the possibility of end-user borrowing to finance solar systems.

Solution B, income tax credits for end-users, operates in the same way as Solution A except that the subsidy is limited to entities whose taxes are large enough to offset against credits, unless a rebate is provided for.

Solution C, low interest loans to end-users, also compensates for the underpricing of conventional energy. Thus Solutions A, B, and C all affect the second-best problems of solar energy.

Solution D, loan guarantees for end-users, increases the willingness of lenders to loan in an unfamiliar market. Thus capital market imperfections are affected. Lenders' risk is reduced below the actuarial level. If this reduction in risk is reflected in lower interest rates, a subsidy is passed on to solar end-users. To a limited extent, therefore, Solution D is capable of affecting second-best problems in the same way that Solutions A, B, and C are.

Solution E, government-provided warranties, or insurance for solar end-users, is designed primarily to reduce the risk to the end-user. The policy that would be optimal from a risk reduction perspective would reduce risk only to its actuarial value, thus charging each end-user an amount to cover the cost of random failure of a solar system. Any further reduction of risk provided by Solution E would create a subsidy to end-users and thus function in similar fashion to Solutions A, B, and C.

Table 4-1. First-Best Problems of Solar Energy and Proposed Solutions

Problems \ Solutions (Proposed)	A Direct Grants to End Users	B Income Tax Credit or Deductions to End Users	C Low Interest Loans to End Users	D Loan Guarantees for End Users	E Govt. provided warranties or Insurance for End Users	F Government Procurement	G Demonstration Programs	H Govt. Equity Investment in Manu-facturing firms	I Tax Benefits for Manu-facturers	J Research and Development	K Federally Funded Training Programs
Private Innovators Cannot Capture Full Social Benefits of Innovation								X		X	
Individual Innovators are More Risk Averse than Society						F	X	X		X	
Individual End Users are More Risk Averse than Society				C	X		X				X
Capital Market Imper-fections	X	A	B	X				X	X		

A. The extent to which an income tax credit affects an end-user's cash flow depends on whether the credit is made available immediately or later when the tax return is filed.

B. The extent to which low interest loans help overcome capital market imperfections depends on their size relative to the required investment.

C. Government willingness to back a loan may be perceived by end-users as a statement of faith in solar technologies and thus reduce the perception of actuarial risk.

F. Large government procurements can only reduce the risk of investment in innovation if announced with long lead times and if multiyear funding i[redacted]uaranteed

Table 4-1 (cont). Second-Best Problems of Solar Energy and Proposed Solutions

Solutions (Proposed) / Problems	A Direct Grants to End Users	B Income Tax Credit or Deductions to End Users	C Low Interest Loans to End Users	D Loan Guarantees for End Users	E Govt. provided warranties or Insurance for End Users	F Government Procurement	G Demonstration Programs	H Govt. Equity Investment in Manu-facturing firms	I Tax Benefits for Manu-facturers	J Research and Development	K Federally Funded Training Programs
Subsidies to Conven-tional Energy Sources	X	X	X	D	E	X			X	X	X
Average Cost Pricing	X	X	X	D	E	X			X	X	X
Environmental External Diseconomies	X	X	X	D	E	X			X	X	X

D. Government-backed loans only represent a savings to the end-user if reduced risk of default is passed through to loan purchases in the form of lower interest rates.

E. Government provisions of warranties or insurance only results in an end-user subsidy if such warranties or insurance are provided at less than actuarially required rates.

Solution F, government procurement, is the most direct way of stimulating the market for solar systems. This solution represents a subsidy only to the extent that procurement is for "uneconomic" solar systems. The magnitude of the subsidy is the difference in cost between a cost effective conventional system and a solar system. In addition to its potential to function as a subsidy to solar energy, government procurement can reduce the risk to innovators if it is announced with lead times sufficient to guarantee the potential innovator a future market.

Solution G, demonstration programs, is another method for stimulating the solar market. Demonstrations of the technical and economic viability of a technology may reduce the perceived risk to the end-user and thus help to remedy a first-best problem. To the extent that innovations within a technology build upon one another, demonstration of a technology may reduce the risk perceived by innovators of related products or processes.

Solution H, government equity investment in manufacturing firms, reduces the private innovator's risk of failure by limiting his capital investment. In addition, the importance of private failure to capture the benefits of innovation is reduced with increased public participation. Thus, two first-best problems are affected simultaneously. The logical extension of federal participation in innovative projects is complete ownership. Complete federal ownership of business, however, is unpopular, and the few examples are special cases.*

Solution I, tax breaks for solar manufacturers, is another method of subsidizing solar energy and reducing the imperfections in the capital market. Solution I thus ultimately affects on the same problems as do Solutions A, B, and C. The distributional effects may be different, however. Solutions A, B, and C subsidize the end-user's purchase, and the manufacturer benefits by the stimulus provided to the market. In Solution I, however, the manufacturer is subsidized and the competitive mechanism is used to ensure that these benefits are passed through to the end-user. Some of these subsidies would probably remain with the manufacturers.

Solution J, research and development provided by the federal government, simultaneously affects five of the seven problems outlined earlier. In addition to providing a direct remedy for the inability of private firms to capture the full benefits of innovation, research, and development funding reduces the risk of innovations to individual firms and, to the extent that research and development ultimately lowers costs, provides a subsidy to the end-user.

Solution K, federally funded training programs for solar architects, engineers, and installers, is an obvious subsidy to solar energy and may have the additional benefit of reducing end-user perception of risk. To avoid

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*The federal government owns TVA and other hydroelectric projects, uranium enrichment facilities, and Conrail, for example.

overuse by the merely curious, participants should share the costs of these programs.

A number of federal policy instruments and programs are appropriate for subsidizing the development and application of solar energy technologies. How many should be undertaken simultaneously? Each of the first-best problems outlined requires a separate policy instrument if the effect of each solution is to be targetable independently. The second-best problems, however, compromise one fundamental problem: conventional sources of energy are underpriced relative to solar sources. One policy instrument (which could be applied independently to different solar sources to reflect the extent to which their conventional competitors are underpriced) is sufficient to correct all three second-best problems. Thus five policy instruments are required to provide generically optimal subsidies for solar energy. If additional policy objectives are added to a solar program, then additional policy instruments are required to independently target the level at which these objectives are met.

In many cases a number of policies could be used to achieve similar objectives. For example, direct grants to end-users, solar tax credits, and tax benefits for manufacturers all are directed toward the solution of largely the same problems. Selection among competing policies must therefore be based on distributional effects, administrative costs, and public attitudes. Among the three options just mentioned the distribution of benefits varies considerably. It is probable* that the benefits from tax breaks for solar manufacturers would be concentrated among fewer recipients than benefits from tax breaks for end-users. It is also probable that providing benefits to solar end-users could be done more cheaply through the existing tax system than by organizing another bureaucracy to administer a direct grant program. The Congress is also usually more inclined to provide special subsidies through the tax system than by direct grants.** In view of the foregoing, solar tax credits appear to be an economically appropriate and politically acceptable method of subsidizing solar energy.

To summarize the results of this section, the broad outlines of an economically optimal and socially acceptable solar subsidy program are presented. First, a major program to compensate for the underpricing of conventional energy sources is required. Subsidies operating on the demand side rather than the supply side of the market are preferable because their benefits are spread more broadly. The major options for providing such subsidies may be ranked in order of increasing progressivity as follows: tax deductions, tax credits, tax rebates, and below-market-rate loans for solar end-users. If the purported federal objective of progressive income transfers is adhered to,

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*In the absence of perfect competition, a portion of the benefits from subsidies to manufacturers would be captured by them. Since there are fewer manufacturers than there are end-users, benefits from subsidies to manufacturers would tend to be more concentrated than subsidies to end-users.

**Subsidies to agriculture are a major exception.

this should be the order of increasing preference. Second, a major program to reduce the end-user's perception of risk is warranted. Here it may be wise to provide different programs for different types of end-users using different technologies. For the homeowner, federal cost-sharing of warranties on solar systems is likely to be the best program. Industrial end-users of large amounts of energy would probably be more influenced by major federal demonstration programs. Commercial users probably stand somewhere in between. Third, a major program is required to reduce the risk of innovation and to compensate for firms' difficulties in capturing the full benefits of innovation. Major federal research and development programs are clearly warranted. In special cases (a solar power satellite system for example), federal equity participation may also be warranted.

SECTION 5.0

THE PROPER BALANCE AMONG FEDERAL PROGRAMS TO SUBSIDIZE SOLAR ENERGY

This section addresses the levels at which components of a broad federal solar program should be conducted. In theory, each program should be increased in size until marginal social benefits from the program equal marginal social costs. This condition should be obtained by running federal programs at a level just sufficient to overcome the problems outlined in the previous section. For example, subsidies given to solar technologies to lower their cost relative to subsidized conventional alternatives should be just sufficient to compensate for the subsidies now acting to reduce the price of conventional energy. In practice, the problem is considerably more complex. Each solar technology competes in only a segment of the energy market; thus, each solar technology should be subsidized at a different level depending on the average subsidy which affects the price of its competitors. Since some technologies compete in more than one market (SHACOB competes with electric resistance heating in some areas and with natural gas in others, for example), a perfect solution is impossible. Determining the required correction for first-best problems is also difficult. Suppose it is desirable to compensate for private innovators' inability to capture the full benefits of innovation by establishing a federal research and development program. To do this at the "optimal" level would require us first to determine what the investment behavior of innovators would be if they could capture the full benefits of innovation. A research and development subsidy would then be provided which, when added to innovators' private investment in research and development, would equal the level of investment under first-best conditions. A further complication is the possibility that public investment would affect the level of private investment and the two would not be additive.

The foregoing discussion illustrates some of the difficulties with a theoretical economic approach to program funding levels. In the actual policymaking process, the politically desired level of solar market penetration in specific markets is determined and then programs are funded to levels that are judged to stimulate that level of market penetration.* Even using this "reverse" methodology, the problem is complex. Market penetration must be established under varying subsidy types and levels.** In cases where the proposed subsidy affects costs directly this is difficult enough; in cases such as research and development subsidies, where prior impact on costs is unknown, it is an extraordinary problem.

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*The whole question is quite analogous to the problem of the optimal level of pollution. From a theoretical point of view, pollution charges should be set at levels that reflect marginal social damages from pollution. Since this level is impossible to calculate, a practical pollution charge would be set to attain a specified level of pollution.

**The MITRE Corporation and SRI International have both developed market penetration models now being used for planning purposes by the Department of Energy.

If the penetration is not the only policy objective, a similar but more complex decision scheme must be employed. Such a scheme was used recently by the Department of Energy's "Solar Working Group" in preparing its review Solar Energy Research and Development: Program Balance (See Hitch et al.). In this study, seven choice criteria were used, only one of which was market penetration. Each choice criterion or "value" was assigned a weight for each of three time periods based on the working group's judgment. Different weights were used for each of seven solar technologies, and total "benefit points" were assigned to each technology. Finally, marginal benefits resulting from increases in research and development funding levels were calculated for each solar technology. This phase of the work relied on judging the likely effect of additional research and development funding on the costs of the various solar technologies. The process led the Solar Working Group to recommend a few major changes in program balance: that solar cooling demonstrations be deferred, that biomass be given additional funding, and that centralized solar thermal electricity be deemphasized. These conclusions depended on the values chosen, their relative weights, the possible effects of various types of research and development funding on future costs, and the effects of cost reductions on market penetration. Judgment was required at each step.

The Solar Working Group/SRI study considered only program balance within the current research and development effort. A more comprehensive study would use a similar methodology to analyze the program balance within other federal solar incentive programs.

Having optimized the balance within programs, the relative merits of each subsidy program need to be analyzed.* No comprehensive study has yet done this, but one is surely needed.

Designing an optimal federal solar program requires several phases. First, the program objective must be chosen. Second, program elements capable of effecting the objectives must be chosen. This is the simple part of the task and can be done largely by using theoretical tools. Third, the relative funding levels for the elements must be selected. This is a difficult and empirically vexing problem that will remain as long as there is a solar program.

*This two-step procedure assumes that the distribution of benefits among technologies within a subsidy program does not change substantially as funding levels are changed. If this is incorrect, program balance within each program and relative funding levels of various programs must be optimized simultaneously.

SECTION 6.0

CONCLUSION

An instructive comparison can be made between the current federal solar energy program and the major economic problems described in Section 3.0, and the generically optimal program to solve them presented in Section 4.0. Each of the major economic problems of solar energy (investor and end-user perception of risk and underpricing of conventional sources of energy) is now being treated at least partially. Investor perception of risk is treated primarily by research and development funding, though this also compensates somewhat for the underpricing problem. End-user perception of risk is treated by the demonstration program and by the development of federal standards for solar energy systems. Underpricing of conventional energy sources is treated in small part by the solar/wind tax credit.

The major omission in the federal solar energy program is the failure to systematically and thoroughly provide a mechanism to compensate for the substantial underpricing of conventional sources of energy. The solar/wind tax credit is a positive step, but it treats only two of the eight generic solar technologies in only one end-user sector. A smaller deficiency is the failure to provide a cost-shared warranty program that would reduce the residential user's risk from product failure. When these omissions are corrected, the remaining issues in the federal solar program will be the funding levels and balance among the various programs. Here, the conceptual discussion in Section 5.0 is relevant. The task is to devise and select a mix of programs to maximize social welfare. This task will require continuing research and evaluation of the nation's energy situation, the potential contributions of the solar technologies, and the time-dependent value of those contributions.

The author's contention is that the value of a given contribution from solar energy technologies increases dramatically through time as conventional fuels become more scarce and expensive. Weingart (1978) notes that the world has only three sources of energy large and long lasting enough to provide adequately for mankind's future: fusion, fission with breeders, and solar energy. With the technological, economic, and environmental feasibility of fusion in doubt and the environmental and safety dimensions of breeder reactors a matter of great controversy, solar energy systems may provide the sustainable basis of mankind's energy future. Despite the public clamor for solar energy now, the increasing value of solar energy contributions argues for a long-term emphasis in solar technology research and development funding. For the present, the most significant federal policy would be the provision of subsidies to compensate for the current underpricing of conventional sources of energy.

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