J. ENVIRONMENTAL SYSTEMS, Vol. 12(1), 1982-83

ACCELERATING THE RATE OF ADOPTION OF SOLAR ENERGY INNOVATIONS IN THE U.S.A.*

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ABSTRACT

Solar energy innovations are likely to concern public and business policy makers in the decade ahead. Sooner or later the focus of concern must move from the general to the specific, from the macro to the micro, from the national level to the regional and state levels. In this paper the diffusion of innovations framework is presented and discussed as an approach capable of explaining and increasing the market share of solar energy innovations. Solar domestic water heating systems serve as a prime example.

INTRODUCTION: THE SOLAR HIGH POTENTIAL/LOW ADOPTION PARADOX

In 1979 a report of the Energy Project at the Harvard Business School titled *Energy Future* swept the United States energy scene over night. As if by magic, policymakers, highly acclaimed scientific journals as *Foreign Affairs* and *Harvard Business Review* and virtually every major newspaper in the country repeated the message of the tightly edited, well written report. Even the White House adopted this message and presented it as the focal point of the United States energy policy. "Conservation: The Key Energy Source" and "Solar America" became the two pillars upon which U. S. energy policy was to rest. "The United

* This paper is based on the author's contribution to *Marketing Solar Energy Innovations* edited by him and published by Praeger's Energy Series, 1981. This paper was prepared at the Hebrew University, where Dr. Shama was a visiting Lady Davis Fellow. Responsibility for the opinions expressed in this paper is the author's alone.

doi: 10.2190/K2KQ-GK2P-WT3C-T8HP
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States can use 30 or 40 per cent less energy than it does with virtually no penalty for the way Americans live . . . " goes the Harvard report, and explains that of the resulting smaller demand for energy " . . . it should be possible to obtain 20 per cent contribution by solar." [1, pp. 182, 213] Not by accident this 20 per cent estimate for solar contribution by the year 2000 is identical to the target solar energy contribution set by the White House on June 20, 1979.

Now, over three years later, the potential for both conservation and solar energy is yet to materialize. But while the White House new administration uses this slow progress to soften its support of conservation and solar energy, I propose an analytical framework capable of increasing the market share of renewable fuels. The explanation for the high potential/low adoption paradox lies in the over-reliance on a macro level, techno-economic approach to energy policy, disregarding both micro-level and behavioral aspects. For conservation energy to supply 30 to 40 per cent of energy services, it must be instantaneously [2, 3]:

- adopted by over seventy-five million U. S. households and millions of businesses, composed of over 250 million people;
- used in amounts and mixes (with fossil fuels) as required by engineering and economic analysis;
- affordable by all U. S. households and businesses;
- physically available to all consumers; and
- perceived as having little or no economic, social, and psychological risks.

Similarly, for solar energy innovations to supply 20 per cent of all energy services services, they must be [4]:

- adopted in one out of every two buildings;
- used by one out of every ten factories; and
- adopted in one out of every six plants.

It takes little expertise, however, to conclude that these conditions can not be easily and quickly met.

The absence of an action-oriented use of the diffusion of innovations framework from business and public policies is a major reason for this high potential/low adoption paradox of solar energy innovations. Business and public solar energy policies have been dominated by technical and economic considerations. And although such considerations are important, they focus on the aggregate estimates only. Rather, the diffusion of innovations theory and research findings focus on the consumer adoption process, and the innovation and its attributes. As such, they can identify bottlenecks in the adoption process, and prescribe easing actions. This is particularly true when one relies on the use of the discipline of marketing. Stated differently, informed use of diffusion of innovations theory and research findings can compress the adoption process and accelerate market penetration.

DIFFUSION OF INNOVATIONS AND SOLAR ENERGY: AN OVERVIEW

The diffusion process is defined as "the acceptance over time of some specific item – an idea or a practice – by individuals, groups, or other adopting units, linked to specific channels of communication as a social structure, and to a given system or values of culture." [5] While there are numerous definitions and perspectives to the study of the diffusion process, several elements are common to such definitions and perspectives. These pertain to the innovation, the adopting unit, the communication networks, the acceptance process, and the time element (see, for example, [6–20]).

As the scope of diffusion literature is very wide, including thousands of research studies, numerous disciplines, and approximately forty journals covering the topic, no attempt is made here to review such literature (for a comprehensive review, see reference [15]). Rather, an attempt is made to synthesize diffusion of innovations research and findings, apply them to solar energy innovations, and make recommendations to policy makers and business executives interested in accelerating the rate of adoption of solar energy innovations among consumers. Accordingly, the basic elements of the diffusion of innovations are discussed and applied to solar energy innovations, and followed by a discussion of specific measures that policy makers and solar energy business executives can use to compress the diffusion process of solar energy innovations.

The Innovation

An innovation is any product, idea, service, or a practice which is perceived as new by the consumer. A product may be well accepted by a group of consumers and still be regarded as an innovation by others. For example, though many consumers in Israel, and parts of California and Florida heat water by solar water heating systems, most consumers in the U. S. may regard this practice as an innovation. Also, an innovation may go through an appearance-disappearance-reappearance cycle. For example, in the mid-1800's wood supplied over 90 per cent of U. S. energy needs, yet today this use of biomass energy is an innovation to most Americans. Solar water heaters which were in use in California and Florida in the early 1900's are another example.

Factors comprising any innovation are totally in the eye of the beholder. Yet, in spite of the differences that one might expect in the perception of numerous individuals, innovations tend to be perceived along a small number of attributes [15]. These perceived attributes, as applied to solar energy innovations, follow.

Relative advantage – Relative advantage is the degree to which the innovation appears superior to prior innovations fulfilling the same needs. Solar energy innovations may be used to provide energy services such as water heating, space heating and cooling, and lighting to the different sectors of the economy. In most cases, these services are presently provided by electricity, oil, and natural gas, used in different amounts and commanding different prices in the various parts of the country. Furthermore, solar energy innovations include a diversity of services – directly or indirectly supplied by the sun – which may be applied to offer different end uses at different costs. Therefore, the advantage of a specific solar energy innovation must be established relative to other energy services, including other solar energy services.

Relative advantage may be established with respect to the cost of obtaining a given energy service, e.g., water or space heating. Cost is the price the consumer pays for a given service such as water heating. The lower that price, the clearer the relative advantage, and the faster the adoption. Presently, consumers are faced with solar energy services which are often more expensive than other energy services. This is the result of heavy subsidies given to non-solar fuels, the exclusion of external cost associated with subsidized fossil fuels, and the relatively small and less experienced solar industry. In fact, when one takes these factors into consideration, the cost of producing solar energy is often cheaper to society than producing fossil fuels. But even when the consumers are faced with higher cost of solar energy services, some of them would prefer such services over those of fossil fuels [17, 21, 22]. Nevertheless, a large market share would necessitate lower prices to allow the post-innovator groups to enter the market.

Risk – Risk is the degree to which economic, physical, functional, and social-psychological risks are perceived as associated with the innovation. Such risks must be minimal in order for the innovation to penetrate the market quickly. As solar energy innovations represent a departure from the mode of obtaining energy services, many consumers may perceive high risk in adopting them. Consequently, the potential for high perceived risk must be reduced before large numbers of consumers would enter the market. This can be done by product demonstrations and information capable of reducing perceived economic, physical, and functional risks, and by social-psychological support.

Compatibility – Compatibility is the degree to which an innovation is consistent with the values and experiences of potential adopters. As solar energy innovations may be used to provide different services to the different sectors of the economy, compatibility is specific to the target group and end-use in question. For example, while solar water heaters may be consistent with values and experiences of residential consumers, they may not fit the industrial requirements for process heat.

Compatibility is a function of the fit of the innovation and the values of potential consumers. Diffusion research normally approached this issue assuming that the innovation is the only change to be considered, while other things are held constant or change insignificantly. In most cases this assumption is quite realistic. For example, except for the innovation itself, one can safely assume that little change was associated with the introduction of aluminum foil, saran wrap, or even microwave ovens. In such cases, the degree of compatibility or "fit" of these innovations is measured against constant values. This, however, is not the case with solar energy innovations. Measuring their fit with social values measured only a few years ago may be establishing fit against values which no longer exist. The U. S. economic and energy crisis which began with the oil embargo of 1973, in combination with other societal factors, is creating a new social order compatible with solar energy applications. Thus, when comparing solar energy innovations with emerging social values stressing conservation and renewable resources, compatibility increases significantly. This is particularly true with regard to simplifying consumers presently estimated at sixteen million and expected to grow to sixty million by 1987, and to one-hundred-twenty million by the year 2000 [23].

Complexity – Complexity is the "degree to which an innovation is difficult to understand and use." [12, p. 146] The more it is difficult to understand and use an innovation, the slower its rate of adoption by potential adopters. Up to the energy crisis of 1973, consumers normally used energy services without much understanding of the way energy was produced, measured, and supplied. Energy was easy to use and "waste," and as long as it was cheap, little mattered. With ten-fold price increase of oil and its manifestation in the price of other energy services and products using energy, consumers are increasingly discovering that their past patterns of using energy are no longer acceptable by their own standards. Cutting "waste" by using conservation measures such as caulking, weather-stripping, automatic thermostat-set-backs, and insulation is practiced by as much as 30 per cent of all households [2]. Thus, such practices are making the consumer more knowledgeable about energy matters, including solar, and reducing complexity barriers to adoption. Necessity is proven once again the mother of invention, rendering the understanding and use of solar energy innovation less and less complicated.

Divisibility – Divisibility is the "degree to which an innovation may be tried on a limited basis." [12, p. 164] Divisibility motivates trial, and compresses the adoption process because small-scale trial entails little risk-taking on the part of consumers. Samples, small packages, try-now-pay-later are common techniques used in the marketing of many consumer goods commanding relatively low prices. However, the purchase and use of solar energy innovations is a major cost or an investment for most consumers. The most basic solar water heaters may cost as little as $2000. After taking advantage of federal income tax credit (40%) and state income tax credit (10-30% in states offering such credits), the real cost to the consumer is a few hundred dollars only (e.g., $700 in California, and $600 in Colorado). But before final decision to invest in the purchase of solar water heaters, most consumers would prefer small-scale trial, which is not easy to achieve in the case of solar energy innovations.

One way to achieve the possibly positive impact of product trial on purchase was recently used by the Tennessee Valley Authority (TVA) with great success. TVA induced consumers to try solar water heating systems, and it supplied them with low-interest loans for the purchase of such systems. As consumers were free to try these systems, and as financial services were made available, this resulted in long lines of applicants for TVA solar programs.

Another trial-inducing method includes programs to demonstrate solar applications to prospective consumers. By showing consumers how a specific solar energy innovation is practiced, consumers are able to examine if it fits their values and lifestyle. As a result of such a "mental trial," purchase motivation may increase or decrease. In the buildings sector, demonstrations may also be used to motivate architects and builders to design and build solar homes.

Although triability of solar energy innovations seem difficult to achieve, it is important to note that once a positive trial is established for one solar innovation, consumers may generalize such an experience to other solar energy innovations and bring about a fast adoption rate for a whole line of solar energy innovations, such as passive and active solar heating and cooling, wind machines, and photovoltaics.

Communicability – Communicability is the degree to which the results of the innovation can be disseminated easily and effectively. Clear-cut results pertaining to those attributes of the innovation which differentiate it from other products in a positive manner constitute effective communication material capable of accelerating the rate of adoption. While demonstrations and other promotional programs may be used, for example, to show potential adopters that solar water heaters may provide more control and autonomy to their users, solar energy innovations are part of a very dynamic, fast-changing, and quite uncertain environment which make easy and effective communication quite difficult.

Policy makers and energy economists often assume that lower cost of solar energy innovations would accelerate the rate of adoption. Therefore comparing the cost of solar energy services to the average and marginal cost of fossil fuel energy services, as well as the unavailability of oil from OPEC at any cost – all realistic scenarios – makes solar energy services increasingly attractive insofar as price is concerned. But while it is relatively easy to communicate cost and performance information, such information is of limited use to the innovators and early adopters now in the market for solar energy services. Communicating noneconomic information may be just as important among innovators and early adopters. For such consumers, convenience, satisfaction, lifestyle, and social consciousness and acceptability considerations may be as important as economic considerations. Thus, communications focusing on cost-performance attributes alone may constitute strategic mistakes in the early stages of diffusing solar energy innovations.

The Adopting Unit

The adopting unit may be an individual or a group that participates in the decision-making process to adopt a given innovation. While for many consumer products and services the individual consumer is the adopting unit, in most cases the adopting unit of solar energy innovations may include the family, the architect, the builder, or an organization. For example, when considering the adoption of a solar water heater, all family members may act as the adopting unit. These members may be looking for different product attributes and exerting different degrees of power, including veto power, in the decision process. In the case of TVA solar program and the Denver Metro Program of the Solar Energy Research Institute, the adopting unit may be composed of the architect, the builder, the sponsor organization, and the family. Admittedly, the greater the number of people composing the adopting unit, the more diverse are their motivations and needs, and the slower is the rate of adoption. Similarly, in the case of adopting solar applications in the industrial sector, production, marketing, and finance executives may take part in the decision to adopt or reject an innovation. Here again, the greater the number of functional criteria the innovation has to satisfy, the lower is its rate of adoption. Nevertheless, as most diffusion studies concentrate on the characteristics of the individual as the adopting units, findings of research studies using the family or other groups as the adopting units are normally reported to fit the framework of early research designs conceiving the individual as the adopter.

Depending on consumer motivation and background, and his/her perception of the innovation's attributes as compared with the attributes of competing products, different consumers go through the adoption process at different times and rates. Those who are first to introduce the innovation are the innovators, followed by early adopters, early majority, late majority, and laggards (and some never adopt an innovation). These groups have been profiled in many studies to suggest their applicability to solar energy innovations [12, 15, 20, 24].

Innovators (2½% of the market) – These are young, of high social and economic status, risk takers, cosmopolitan, and prefer impersonal communication sources.

Early adopters (13½% of the market) – These too are young and of high social and economic status, seek respect, and are extremely capable opinion leaders. Once they adopt an innovation, others are sure to follow.

Early majority (34% of the market) – These are of average social and economic status, love to show or tell their peers of products they purchase, and are followed by the late majority.

Late majority (34% of the market) – As these are of below average social and economic status, they are skeptical about adopting new products. Adoption occurs when the price is low enough and the pressures to adopt are strong.

Laggards (16% of the market) – Last to adopt, these consumers have low social status and income, their values are very traditional, and they are reluctant to purchase and use new products and services.

Channels of Communication

Potential adopters of a given solar energy innovation may obtain information from two different yet complementary channels of communication. One is the mass media which includes television, radio, and magazines, and the other includes personal sources such as peers, friends, and neighbors. Generally, mass media are effective in reaching a great number of individuals and informing them of the innovation and its possible uses. On the other hand, inter-personal communications involve a very limited number of people, but are very effective in convincing the individual to adopt the innovation.

In either case, communicating to the potential adopter through an opinion leader enhances the effectiveness of the communication channel and the effectiveness of the message. An individual who influences the opinion and preference of others, the opinion leader may:

1. endorse the innovation on the mass media;
2. interpret or discuss relevant mass media messages with group members, thus increasing awareness, knowledge, and interest in the innovation; or
3. provide persuasive information to a group member.

Whether one uses the first of the above modes, which stresses source credibility, or the second mode, utilizing the "two step" (message → opinion leader → group member) or "modified two-step" (message → opinion leader and group member, opinion leader ↔ group member) flow of communication, or the last mode, focusing on opinion-seeking, in all such cases the effectiveness of the individual in leading the opinion of others is a function of his credibility, itself a function of perceived expertise and trustworthiness of the opinion leader [25, 26]. Thus, the more the opinion leader is trustworthy and has expert credentials, the more persuasive he is. As it is logical to assume that opinion leaders are usually trustworthy, their perceived expertise relating to the innovation determines the limit of their influence on group members.

The Adoption Process

The adoption process refers to the various psychological stages that potential adopters go through from first hearing about the innovation to their final adoption or rejection of it [12, 15, 20]. In the context of solar water heaters, these include:

1. The *awareness stage* during which the potential adopter learns of the existence of the innovation of solar energy water heaters but has little information of its attributes and functions.
2. *Interest stage* during which the consumer acquires information about the innovation and its functions. Combined with the awareness stage, the interest stage results in knowledge, comprehension, and cognitions about solar energy water heaters.
3. *Evaluation stage* during which the potential adopter compares water heating services provided by solar and non-solar energy sources. A "mental trial" takes place at this stage, which may end up with a decision to seek actual trial of the innovation, reject it, or "wait and see."
4. *Trial stage* during which the consumer may actually but temporarily use hot water heated by solar energy systems. Again, depending on his experience, the consumer may decide to adopt the innovation, reject it, or gather more information about it before final decision.
5. *Adoption stage* during which the consumer decides on full scale purchase and use of solar water heaters.

As mentioned earlier, the speed with which consumers go through these psychological stages depends on their background and on the attributes of the innovation. Furthermore, sometimes consumers may skip some of the stages and make fast adoption decisions. For example, in the case of solar water heaters, the speed of making an adoption decision, which may involve skipping some of the mental stages, is a function of the importance of the decision whether or not to purchase a solar water heater, the extent to which heating water by solar energy is positively differentiated from other means of heating water, and the ability of the consumer to take risk.

An important consideration in assuring smooth and speedy adoption is identifying and solving problems which may otherwise result in rejecting the innovation. Factors which may contribute to the rejection of solar water heaters at any stage of the adoption process may relate to one or more attributes of the innovation, e.g., high first cost, personality characteristics of potential adopters, e.g., dislike of change, and a social system in which energy market realities are so distorted as a result of subsidies for non-solar energy services that positive solar economics are difficult to establish. This last factor is of particular importance for most solar energy innovations, which only energy policy makers can help solve.

Time and Space

Time is of central importance in diffusion theory. The success of an innovation is normally measured by the length of time it takes the innovation to be adopted by a given population. In addition, adopter categories are defined and classified into different groups depending on *when* they adopt the innovation, and even their decision-making process beginning when they first become aware of the innovation until final adoption attest to the centrality of the time dimension in the adoption process. Furthermore, time and timing are also important to those interested in accelerating the rate of adoption of a given innovation.

Temporal variables are the outcome of consumer motivation, socioeconomic status, and perceived innovation attributes which determine the speed of adoption. As a result, the ability to predict the time of adoption may mask many behavioral variables which can be influenced by measures capable of accelerating the rate of adoption [20]. Equally important is that models which exclude behavioral variables may lead to misdirected measures to accelerate the rate of innovation adoption. For example, researchers employing solar energy market penetration models which focus on cost and performance as their main variables often recommend price reduction as a way to increase market penetration. But as diffusion research has established, early adopters are less interested in price and more in innovativeness, stressing the last attribute may be much more effective in increasing sales, i.e., adoption, to the early adopters now in the market.

Of particular importance to the diffusion of solar energy innovations in the U. S. is the fact that some of these innovations are well diffused in other countries. For example, in Israel, solar water heaters have penetrated over 40 per cent of the residential market, and solar ponds are producing usable energy. European countries such as Sweden and Denmark developed efficient energy use habits. By careful analogy, the experience of such countries may provide useful information to accelerate the adoption of solar energy innovations and energy conservation by American consumers.

DIFFUSION THEORY AND SOLAR ENERGY INNOVATIONS

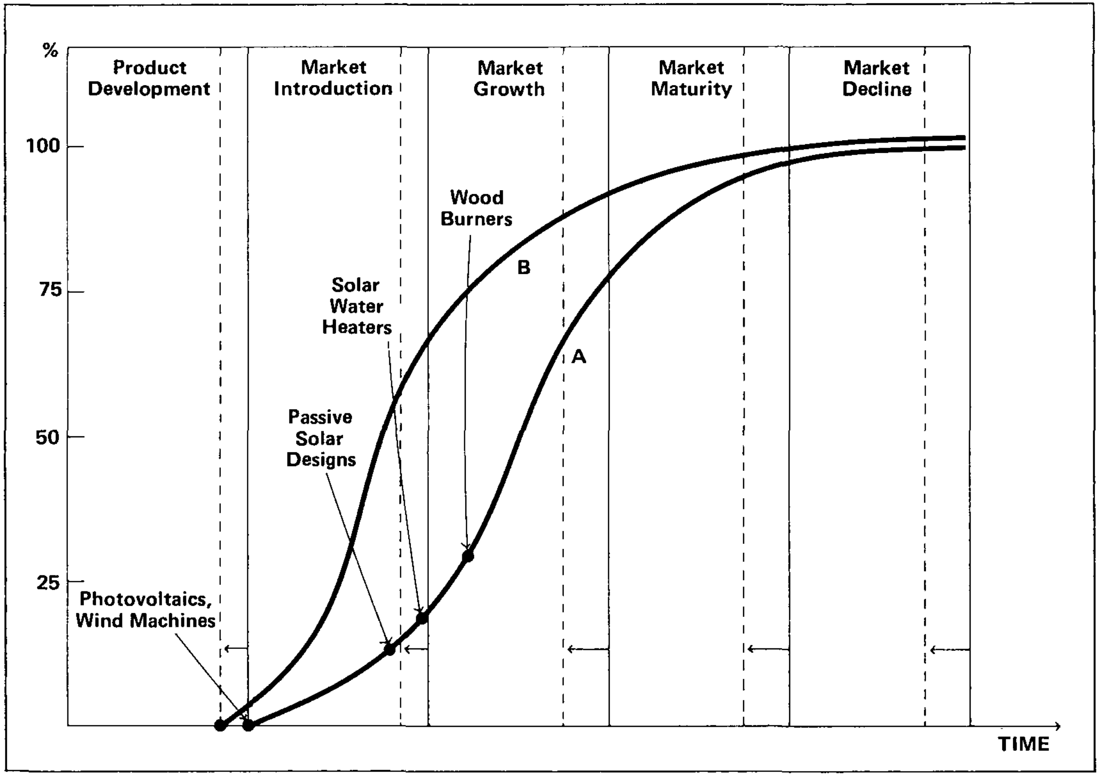
Solar energy may be discussed from two different perspectives: the diffusion of innovations perspective, and the social change perspective. Though conceptually any innovation changes behavioral and consumption patterns, the social change perspective implies wide range changes in behavior and consumption, as well as changes in social and political structure. Thus, while the diffusion perspective views solar energy technologies as new energy services provided by renewable sources, the social change perspective views it as a manifestation of the changing American society.

Social Change Perspective

The oil shortage of 1973, and the related inflation during stagnant economic growth, have brought dramatic changes in the values of many Americans. As real income grew very slowly in the 1970's and declined by as much as 10 per cent during 1981, Americans became extremely frustrated and unsuccessful in actualizing their past values of material growth and conspicuous consumption. As a result, a growing number of Americans is reverting to simpler life, using energy more efficiently, and adopting solar energy innovations [27]. Viewed this way, the use of solar energy innovations is an important expression of the changing values of Americans. Other expressions include lifestyle and shopping behavior changes, as well as changes in social and political life. These may have led to the sweeping changes in national leadership in the aftermath of the 1980 national elections. Discussed in this mode, solar energy innovations enter the realm of social philosophy and symbolize a turning point of the U. S. social, economic, and political make-up. Though this perspective is broad and intellectually appealing to the writer, the traditional diffusion perspective is more widely accepted and supplies a more effective frame of reference to energy researchers and policymakers alike. For this reason, it will be utilized throughout this article.

Diffusion Perspective

Solar energy services may be discussed from a diffusion of innovations perspective in that they represent energy services which are perceived as new by most consumers of energy services in the U. S. Thus, Wisenblit [28], LaBay [29], Roessner et al [16], Shama [17], Warkov [30], and Warkov and Meyer [31] establish the validity of applying the diffusion framework to solar energy technologies. Accordingly, the solar energy technologies are energy innovations in the early stages of their life cycle. This is shown in Figure 1. As can be seen, while solar water heating systems and wood burning stoves are well into the innovation stage, photovoltaics and wind machines are still in the pre-market introduction stage. It has often been argued that by infusing resources into the product development stages of solar technologies which precede their diffusion process, it may be possible to compress product development activities, and accelerate the rate of adoption of solar technologies; that is, to move the diffusion curve from A to B. Intuitively, the more money that is committed to perfecting a product (e.g., solar water heating systems) and promoting it in the market, the more likely that the product can be quickly perfected and sold to consumers. Monetary resources, however, cannot always substitute time and motivate purchase. In fact, such a strategy can backfire and slow product development and adoption rate. More important, however, is that the diffusion framework is sufficiently comprehensive and reliable to improve our knowledge of solar energy innovations, and identify ways to accelerate their diffusion in the market place.



SOURCE: Constructed by the author.

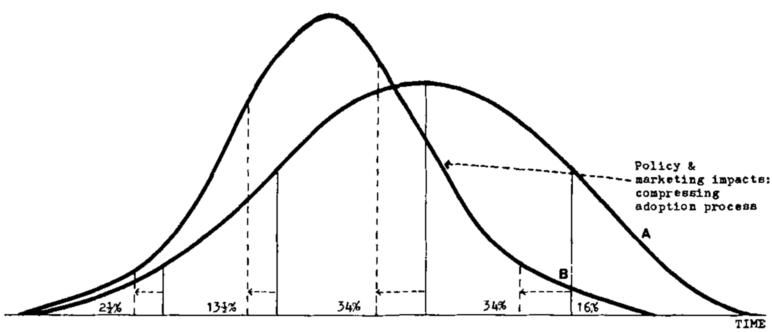
Figure 1. The diffusion of solar energy innovations.

Figure 2 depicts the diffusion of innovations process, adopter categories, and marketing and policy variables that may be used to accelerate the rate of adoption. Solar water heating systems are used for the purposes of this analysis, but in principle the analysis is applicable to other solar energy innovations. Here again, two diffusion curves are depicted. Curve B compresses the process of Curve A. This is the best result that policy makers and marketing management can hope for. Even then, carefully and flexibly formulated policies and marketing programs capable of adapting to different market and consumer needs at the different stages of the adoption are required.

Policy measures as part of a national solar energy policy, itself a component of energy policy, and marketing mixes developed by marketing managers can affect the rate of consumer adoption of solar water heating systems. This can be achieved by careful product, price, promotion, and channels of distribution decisions which make the adoption of such systems attractive to the consumers.

Product – Superior innovations which are consistent with what consumers value, and are easy to understand, communicate, and try on a small scale, get adopted quickly. Therefore, to accelerate market penetration of solar water heating systems policy and marketing measures must facilitate the above consumer perceptions. As can be seen in Figure 2, management may accelerate the rate of adoption by stressing the innovativeness of solar water heating systems before the innovators and early adopters; relative advantage – before early adopters, while product differentiation and market segmentation become important beginning with the early majority group. Finally, while a limited line of solar water heating systems may be sufficient to achieve market recognition at the innovation stage, a more extensive line may be necessary later on to appeal to different market segments.

Policy measures can also accelerate market penetration by product-related activities. In the case of solar technologies, product policy measures start before market introduction. Support to research and development activities can help develop better products quickly, so market introduction activities can start fairly early. Some research and development support has been given by the federal government to almost all solar technologies. Given indiscriminately, however, the magnitude of government R&D support may help develop solar technologies with relatively limited market potential. Thus, it is important that government R&D support for solar technologies be based on their expected contribution to whatever policymakers value, e.g.: energy independence, clean environment, etc. Consistent with this, the Department of Energy sponsored studies to quantify the expected contribution from different solar technologies, or otherwise shed light on the values associated with the use of solar energy [32, 33], while other researchers proposed the use of multi-attribute models to quantify the market potential of various solar technologies [34]. This requirement is both logical and dangerous. It is logical because it requires that investments in R&D and later



Marketing & Policy Factors	Innovators	Early Adopters	Early Majority	Late Majority	Laggards
PRODUCT:					
Innovation attribute	Innovativeness	Innovativeness, relative advantage; Low risk	Compatibility; Warranty; Servicing		
Product concept		Less complex product functions			
Product differentiation			Importance of product differentiation (segmentation)		
Product line	Limited	Limited-extensive			
POLICY MEASURE	R&D Procurement	Demonstration; Consumer protection; Standards & labels	Trial		
PRICE:	Skimming(high) or Penetration (low price)	Skimming or penetration	Penetration; Promotional pricing(e.g.quant. discount)		
POLICY MEASURE		Price reduction for trial; Tax credits & rebates; Financial services (e.g.Conservation & Solar Bank)			
PROMOTION:					
Message		Inform	Persuade	Persuade & remind	
Media	Specialized media	Specialized media	Mass media		
Budget	Big	Big			
Personal Selling	Light	Light	Heavy	Heavy	
Publicity		Heavy	Heavy	Light	
POLICY MEASURE		Demonstration			
DISTRIBUTION:		Selective	Mass(market saturation)		
POLICY MEASURE		Support wide distribution			

SOURCE: Constructed by the author.

Figure 2. Adoption curve, policy measures, and marketing strategy: applications to solar energy innovations.

support to commercialization efforts be based on some measures representing return on investment or "profitability" to society. However, it may also be dangerous in that it may be based on scant and very biased data. Consequently, the use of this procedure should be examined periodically.

Once the product is ready for market introduction, policy measures supporting procurement, demonstration, and consumer trial may accelerate adoption rate. Setting standards, labeling requirements, and consumer protection, which ensures product performance and reliability and reduces economic risks on the part of consumers, are additional policy measures capable of accelerating market penetration. However, such policy measures may also have a negative impact on the adoption rate of solar technologies.

Price – Innovations tend to be more expensive at the market introduction stage, and solar energy innovations are no exception. For example, the cost of domestic water solar heating systems ranges from $2000 to $3000, while energy saved by their use makes only a small reduction in monthly energy bills. Given consumers' preference for low first cost, which has been heavily reinforced by business practices, a perceived reduction in first cost is a necessary requirement to increase consumer adoption of solar water heaters [35–37]. Consequently, setting high prices to skim the market may be a business mistake. Rather, setting lower prices that would enable market penetration and profits through a high sales volume is smart business. But even relatively low prices still require high first cost, unless financial services are provided to reduce the burden of first cost. Examples of such services include low down payment and monthly installments as practiced in the automobile industry, and rolling the cost of the solar system into the mortgage loan for the building. Though many experts have made such propositions, the industry – which in the case of solar water heaters may include builders, banks, homeowners or homebuyers, and solar energy companies – has been slow to respond. While this is consistent with the discussion of the adopting unit in this paper, it may be significant to note that high first cost of solar energy innovations may be used as a leverage for greater loans to builders. For example, Posner and Sussman show that builders using solar energy in their buildings can qualify to larger loans, thus leveraging their investment even further [38]. This is because carrying charges such as energy bills are reduced when solar systems are incorporated in new buildings.

Realizing that high prices deter consumers from buying solar water heating systems, federal and state policymakers stress price reduction measures for solar installations and solar retrofits. Thus, federal tax credit is 40 per cent of the cost, and state tax credit – in states providing such a price incentive – ranges from 10 to 30 per cent. While these policies reduce first price significantly (e.g., in Colorado the price of solar water heaters is reduced to $600 to $900, depending on the list price), it may be important to note that consumers must pay the full price when they purchase the system and wait as much as a year to receive the tax credit or "rebate." While these policies amount to greater incentives to better-to-do consumers, a more immediate connection between the purchase and the "rebate" may increase the number of consumers who purchase solar systems. Paying an on-the-spot 100 per cent of list price and waiting as much as a year to receive the state and federal credits, or paying an on-the-spot net price (only 30% of list price in Colorado for an example) are two different stories for many consumers. Thus, if price reduction policy measures are desirable, they must introduce a more immediate connection between price and tax incentives in order to be fully effective. On the other hand, raising the list price just because government now pays part of the system may be a misguided strategy on the part of solar manufacturers and installers.

It should be noted, however, that over-reliance on economic incentives may be a mistake, too. In the extreme and theoretical case, if one were to offer solar water heating systems free of charge, consumers would suspect the quality of such systems and the motivation behind the offer. That is, economic incentives *alone* may have only limited value in accelerating the rate of consumer adoption. For example, a recent study shows that although economic incentives may be important, adoption rate increases significantly when economic incentives are part of integrated policies stressing information, consumer protection, product quality, as well as economic incentives [39].

Promotion – The main function of promotion is to facilitate the sale of products and services by creating awareness, interest, and preference for them. Depending on the nature of the product, its life cycle stage, and its target group, different messages and channels of communication may be selected [40]. As can be seen in Figure 2, informative messages may be required at the early stages of the diffusion of solar energy innovations, while more persuasive messages are generally more effective later on. Similarly, specialized media such as newsletters and professional magazines are more effective in the innovation and early adopter stages, while mass media may be necessary as the early majority enters the market. Likewise, only light personal selling efforts may be required at the early diffusion stages, and a more intensive effort may be necessary later on to offset competitive forces entering the market. On the other hand, heavy publicity may be required at the early diffusion stages.

Equally important is the size of the promotion budget. Normally, promotion budget is determined by sales volume. As sales are nonexistent or are very scant when solar energy innovations are introduced to the market, the only sales figures which might be available are expected sales. But even linking promotion budget to anticipated sales may not create a strong enough stimulus to increase adoption rate. Rather, it is more logical to conceive promotion budget as an investment whose size is determined by expected profits. This way, a big promotion budget may be necessary to inform and persuade a substantial number of consumers that will set the diffusion on a smooth course. This is of particular importance because as much as 20 per cent of the target group has to be aware of the product before adoption can take place.

Finally, although promotion may be necessary to accelerate the adoption rate of solar energy innovations, it is by no means sufficient to achieve this goal. The most important group for a smooth adoption is the innovator group. Unless innovators purchase and use solar water heating systems, the early adopters will not enter the market. However, as innovators are independent and almost detached from promotion campaigns, they are almost immune to persuasive messages. At this stage, product perfection activities and awareness-creating messages may be the only strategy available to reach the innovators.

Policy makers have traditionally avoided the use of promotion to accelerate the rate of desired behavior on the part of the public. Only in cases of public health or national security did policy makers make some exceptions. For example, in order for the Department of Energy to support a "Low-Cost/No-Cost" campaign which distributed a shower head flow restricter and a list of eleven other conservation measures in New England in the Fall of 1979, it had to treat it on an ad-hoc experimental basis which may motivate state government to follow suit. Indeed, the state of Colorado adopted the Low-Cost/No-Cost promotion program in the Fall of 1980, and other states are said to follow suit.

On the other hand, demonstration programs have always been supported by the federal government as a means of promoting the use of desired products and practices. The federal solar demonstration program so far included primarily the demonstration of active solar heating and cooling, while programs under way at present extend the demonstrations to other solar technologies, e.g., Photovoltaics, and wind machines. Yet, because demonstrating solar energy innovations may take time, and so would their impact, a more direct promotion program may be desirable. But while federal government may avoid such an approach, state government, local government and civic groups are becoming more active users of such a direct approach. Thus, a growing number of energy extensions are teaching their students how to install solar water heaters in their homes, and otherwise promote the use of energy from renewable sources.

Finally, the diffusion of solar energy innovations may be accelerated by using mandates. As promotion is aimed at changing behavior, mandates pertaining to solar energy innovations may be regarded as a form of promotion. Such mandates may range from mild ones requiring, for example, cost performance information about solar panels, to strict ones requiring, for example, the use of specific passive and active solar energy innovations. At best, mandates can speed-up the diffusion process. Mild mandates coerce consumers less, and they can be flexibly applied. On the other hand, strict mandates are more coercive and effective in bringing about desired results, but they may be quite dangerous in dictating actions which otherwise would never be taken.

Distribution – The distribution of solar energy innovations, as in the case of all products and services, pertains to their flow from the producer to the final consumer. It may be a simple system whereby the producer distributes the innovation directly to the adopter, or a complex system whereby the innovation goes through wholesalers and retailers before reaching the final adopter. The specific distribution system is normally determined by the nature of the innovation, forecasted sales, and consumer and producer preferences. Changing the distribution system as market conditions change is part of distribution strategy. This is of particular importance to solar energy innovations, as market conditions pertaining to them may change drastically.

Distribution establishes the time and place availability of the innovation, as determined by consumer needs. Thus, when the market is very small and demand is weak, as is the present case of some market-ready solar energy innovations, a simple and very selective distribution system (e.g., producer → consumer) may be most efficient. When the market grows and demand strengthens, as may be the case of solar water heaters in California and Florida, mass distribution may be more efficient in satisfying "time" and "place" needs of consumers.

Functions often performed by distribution channels to ensure efficient delivery (and even motivate sales) are transportation, storage, economic and physical risk-taking, financing, selling, and market research. The specific functions or mix of functions performed by the distribution channel depends on the preferences and strength of producers and distributors, competition, as well as decisions concerning pricing and promoting the innovation in question. Nevertheless, as the market grows, selective and not easily accessible delivery systems may hamper the rate of consumer adoption. Such may be the case of solar water heaters. It is estimated that as much as 253,000 systems are in place presently, while other estimates are much higher. Perhaps more significant, is the exceptionally positive attitudes of consumers toward solar energy systems (see, for example, Farhar and Unseld, 1982). Though this does not necessarily mean a strong market for such systems, it does indicate a potential for such a market if the "right" product (i.e., solar energy innovation), is offered to the "right" consumer, at the "right" price, and at the "right" time and place. Experts now claim that the selective, almost intermittent distribution system for solar water heaters hampers their rate of adoption by consumers, particularly in California and Florida. Put differently, consumers who are interested in buying solar water heaters have a hard time locating the product, let along being able to take advantage of comparative shopping to reduce their economic cost and risk, and reduce future feelings of regret or cognitive dissonance. Thus, a recent study by the U. S. Department of Energy [41] concludes that "the lack of industry infrastructure often associated with new technologies is an impediment to solar commercialization." Furthermore, as solar energy innovations are not designed for direct consumption or use by the consumer, but rather a product or a practice to be used as part of a system(e.g., solar water heater as integrated in the building structure and energy requirements) the delivery of solar innovations poses a challenge to their speedy diffusion. First, the ultimate adoption unit is normally more than one person; it may be the family in case of residential solar energy applications, and the corporate policy makers in case of commercial and industrial applications. Second, different facilitators may be needed before adoption can take place. Quality installation services are necessary in the case of adoption by homeowners; willing builders and architects are necessary in the case of adopting solar energy use in new homes; and in both cases cooperative bankers are essential. Third, the innovation must be available at the right time and place for consideration by the builder, the installer, and the homeowner. Considering the particularly conservative nature of the building industry, indeed these are very serious challenges to efficient distribution of solar energy innovations [42, 43].

Short of taking over the distribution functions, policy makers can do very little to stimulate them. However, by considering distribution issues carefully, policy makers can influence the establishment of effective and efficient distribution channels. For example, the Conservation and Solar Bank, and the Residential Conservation Service facilitate the establishment of distribution channels for both conservation and solar energy innovations in that they make the purchase of such innovations possible, and require utilities to supply homeowners whose homes are audited with more information about solar energy innovations applicable to their homes, the cost of such innovations, and a list of reputable distributors and installers. On the other hand, other federal programs such as the demonstration program of solar water heaters have little impact on distribution channels. Either way, the *timing* of such programs is of crucial importance, as starting them too early may have a negative or no impact, and starting them too late amounts to shipping coal to New Castle.

CONCLUSIONS AND RECOMMENDATIONS

The absence of a marketing-oriented use of the diffusion of innovations framework from business and public policies is a major reason for the high potential/low adoption rate paradox which characterizes solar energy innovations. Business and public policies regarding solar energy innovations thus far have been dominated by techno-economic considerations. Although such considerations are important, they are focussed on production only. On the other hand, the diffusion of innovations framework focuses on both the consumer adoption process, and the product and its attributes. As such, it is action oriented and helps identify bottlenecks in the adoption process, and specify easing actions. This is particularly true when one relies on the use of the diffusion framework from the point of view of the disciplines of marketing.

Consistent with this, the following conclusions and recommendations are based on marketing use of diffusion of innovations framework, and are intended to help those interested in accelerating the diffusion of solar energy innovations.

Develop and perfect solar energy products – Business should develop and perfect solar energy innovations before introducing them to the market. As some manufacturers of solar domestic hot water (DHW) systems can attest, introducing products which are not fully ready does more harm than good. It seems that by now most manufacturers are aware of this quality prerequisite to market introduction.

In addition, because solar energy innovations may be interrelated, their interrelatedness should be taken into consideration in developing energy systems. For example, passive solar energy measures such as building orientation reduce space heating needs from an active solar space heating system. Similarly, developing a product line in any given category of solar energy innovations may be desirable, because different consumers may need different products in the line.

Government too, may help the development of quality products by well timed support for demonstrations and procurement contracts.

Define solar energy products carefully – Consumers do not need energy per se, nor its hardware. Rather, the need is for energy services to heat, cool, and light. As a result, solar energy innovations must be defined as *service innovations* and promoted as such. This not only provides a comfortably wide-scoped definition, but also requires more resources and managerial attention to servicing and maintaining solar energy systems. Accepting this definition, for example, transforms a producer and installer of solar energy water heaters into a company providing water heating services.

Rely on relative advantage of solar energy innovations – Rather than treating energy as a homogeneous product or service, relying on attributes unique to solar energy innovations can accelerate adoption among innovators and early adopters who are responsible for the success or failure of most innovations. Solar energy is safe, clean, and renewable. Additionally, use of solar energy innovations may ensure at least some degree of energy independence and autonomy. Such unique attributes may indeed justify premium prices.

Demonstrate solar energy innovations – Demonstrations are an effective tool to inform and educate the consumer and reduce the risk that he perceives in purchasing and using the innovation. This is particularly true with regard to solar energy innovations, because such innovations are different from other services which provide energy. Timing of the demonstrations is of critical importance. The product must be fully ready technically, and target consumers must genuinely be interested rather than the Sunday sightseeing crowd. Government support to demonstration projects too can contribute to the acceleration of solar energy innovations. And here again, timing is very important.

Target solar energy innovations – Presenting different product concepts, attributes and lines to different adopter categories is essential for speedy market penetration. Targeting is determined by consumers needs and the benefits that they derive from a given innovation. This is also the basis for market segmentation whose use increases sales and market share, i.e., accelerates the rate of adoption. For example, the custom home builder may be interested in passive solar systems and solar DHW systems, while farmers in the windy regions of the Northwest are interested in wind energy.

Introduce regional policies – Regional differences in consumer needs for energy services, particularly those for heating and cooling as they are impacted by cost and competing fuels, and consumer socio-economic status must be introduced in business and government policies regarding solar energy innovations. Business which usually treats regional considerations in its market segmentation strategy is yet to fully realize the importance of such considerations. Similarly, government policies toward solar energy innovations did not consider regional differences adequately. Only in the past two years did policymakers become aware of the importance of such differences and the possibilities that state and regional solar energy centers afford them. Such possibilities include not only accurate information about smaller geographical areas, but also the use of the centers above to implement and "distribute" federal policies regarding solar energy innovations. Unfortunately, the new administration does not seem to take advantage of these lessons.

Help the consumer decision making process – Consumer decision making process to adopt or reject an innovation follows a number of well delineated psychological stages (awareness, interest, evaluation trial and adoption). A different information mix is needed at the different stages of the adoption process. Factual product information designed to create consumer awareness of the innovation should be used in the early stages of the adoption process; later, product information must convince the consumer that the innovation can meet his specific energy needs, and create purchase motivation. Similarly, different communication channels should be used at the different stages of the adoption process. Generally, while mass media is effective in creating awareness, specialized media is more effective in persuading consumers.

Consider the do-it-yourself market – The do-it-yourself market for innovations such as solar DHW systems and wind machines may be large enough to justify separate do-it-yourself product lines. Such innovations are simple and consumer interest in hands-on-experience with the innovation, and in cost-cutting is strong enough to merit serious consideration. Energy extensions offering weekend courses teaching how to install solar DHW systems are generating increasing numbers of participants. Such participants are likely to generate positive and powerful word-of-mouth advertising upon which the business sector may capitalize.

Reward the use of solar energy innovations – The use of solar energy innovations may be rewarded financially and psychologically. Financial rewards are cost-reducing economic incentives. These are effective only when high prices are barriers to adoption. Psychological rewards are messages which positively reinforce the purchase and use of solar energy innovations. Neither of these rewards is essential in the innovation stage, but both are important as an increasing number of early adopters enter the market; they become critical as the early majority enters it. Federal and state tax credits for the adoption of solar energy innovations are an example of economic incentives, whose impact may have been limited because they are not widely known, and because consumers have to wait up to a year to receive their rebate. A more immediate connection between price and tax credit is highly desirable. Cancelling the solar tax credit in the future will slow the adoption of solar energy innovations because such an action will deter the cost conscious consumers from entering the market.

Offer financial services – Because almost all solar energy innovations represent major costs or investments to the consumer, the availability of financial services is essential to speedy market penetration. Consistent with this are the Residential Energy Conservation program, and the Conservation and Solar Bank which are designed to make financial services more available. This, however, is short of a full line of financial services which may be needed. Should these services be cancelled, the negative impact on the rate of adoption is quite clear.

Ensure realistic price comparisons – As long as the price of conventional energy services is subsidized, and as long as it does not reflect marginal social cost, potential adopters of solar energy innovations may decide against adoption. Only government policy can change this artificial market bias, and the recent decontrol of oil prices is a step in the right direction.

Use penetration price policy – Setting prices relatively low so as to gain a large market share can accelerate the diffusion of solar energy innovations. Furthermore, a large market share may not only result in market leadership with regard to a given solar energy innovation (e.g., active heating systems), but also with regard to other innovations (e.g., active cooling systems).

Ensure appropriate distribution – Distribution channels must be in place before an innovation can penetrate the market. Selective and even intermittent distribution may be adequate in the very early stages of the diffusion, but less selective distribution is necessary for speedy diffusion at later stages. Presently, the absence of credible mass distribution channels for innovations such as solar DHW systems slows distribution at least in some regions of the country. Government, and especially business, should encourage widening the distribution of solar energy innovations both as an adjustment measure to the growing market, and as a tool to expand it.

Discourage energy inefficient practices – In addition to rewarding the adoption and use of solar energy innovations, discouraging energy inefficient practices may further enhance solar energy innovations. For example, deregulating oil prices as well as differential pricing such as increasing block utility rates, and demand billing, may change demand for energy services in favor of adopting some solar measures.

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