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Technology Utilization: Incentives and Solar Energy

A technology delivery system is used to explain the role of incentives in stimulating public use of solar energy.

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In recent years, the federal government has been increasing its investment in research and development for clearly perceived public needs, with the approval and, in some cases, the urging of the Congress. Unfortunately, the existence of a public need does not necessarily correspond to a public market and, without being able to perceive a potential market, industry cannot begin to put the results of federally financed R & D to work in the form of new products, processes, and services for the public. What is even more unfortunate is that many a time, even in the presence of both a clearly perceived market and a public need, industry alone cannot put the R & D results to use for the benefit of the public. The solar heating and cooling of buildings is a good example of this situation, and is used for illustrative purposes in this article.

During the past 30 years, the R & D activities funded by the federal government were mostly for its own use, and were selected according to the needs of the various missions it had to accomplish. These R & D results were put to use by the government simply paying for the applications. For example, defense oriented R & D results were put to use through defense procurements. There was little conscious effort on the part of the Department of Defense to foster civilian applications of R & D results that were generated for its own use. Similarly, the results of R & D that were federally funded for the National Aeronautics and Space Administration (NASA) were promptly put to use for NASA's own applications through procurement. However, the application of NASA's R & D results to civilian purposes was a different situation altogether. While required by basic NASA legislation, such application did not take place naturally to any great extent (*1*). Because it was recognized that deliberate effort would be required to bring about civilian application of this R & D, the Technology Utilization Division was established as a part of NASA (*2*).

During the 1970's and 1980's, increasing amounts of federal R & D funds are expected to be spent for civilian needs in such agencies as the Department of Transportation, the Environmental Protection Agency, the Law Enforcement Assistance Administration, and the National Science Foundation. These federal agencies do not provide the primary market for the application of the R & D results in the way that the Department of Defense does, however. Although federal grants are made available to states and local governments to help pay for pollution control systems and transportation systems, for example, it is the federal grantees who decide whether to spend the funds on new or conventional technology. In some instances, the would-be purchasers of applications of federal R & D results have been unable to find a manufacturer or supplier willing to use the desired new technology.

Thus it is evident that federal research administrators must attempt to stimulate the application of federally funded, civilian oriented, R & D results without relying entirely on federal procurement for the applications. Some administrators may see this as a trivial task to be relegated to the "free workings of the marketplace" and, when confronted with situations in which there is ample technical knowledge but an unfilled gap between a public need and a public market, they will seek refuge in funding studies of "imperfections" in the free workings of the marketplace. Others may see this as an impossible task without federal procurement of some sort. However, the civilian oriented federal research budgets are large enough (about $7 billion for fiscal year 1975) for it to be worth exploring the alternatives.

Definition of Terms

Everything said here is in the context of federally funded R & D, no matter who the performers of R & D are. Technology utilization in this article refers to the application of R & D results for which they were intended. This is in contrast to technology transfer, which refers to the application of new technology to purposes other than those for which it was originally intended (*3*). For example, the application of defense R & D results to water pollution control would be considered as technology transfer in the context of this article, but the application of water pollution R & D results to water pollution control would be considered as technology utilization.

Technology transfer, as defined above, has problems of its own which I will not discuss here (*4*). What I will discuss is technology utilization by industry, when the R & D has been directed toward civilian use but paid for by the federal government.

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The Technology Delivery System

It takes a number of different types of institutions, interacting with each other, to introduce a new technology in the form of a new product, process, or service, into the marketplace, be it a federal marketplace or a civilian one. For example, universities may be involved because they provide the education required for utilization of the new technology; industrial and commercial institutions participate because they manufacture and sell the products based on the new technology; even lending institutions play an important role in making funds available for the manufacture or civilian purchase of applications of the new technology.

The notion of a technology delivery system (TDS) was employed by the National Academy of Engineering (*5*) to represent the complex processes by which knowledge in natural and social sciences is deliberately applied to achieve desired outputs of consumer amenities having social values.

Each technology has its own delivery system consisting of a number of interacting components, and each component consists of a set of institutions that perform a common function. Looked at from this point of view, one component of a TDS could consist of a set of research-performing institutions such as universities, nonprofit research institutes, and small R & D companies. Another component could be a set of institutions that manufacture products. A third component could be a set of institutions that distribute the product. A fourth component could be a set of lending institutions that make operating funds available to other components in the TDS.

Before a new technology can reach the marketplace in the form of a new product, process, or service, all of the components of the appropriate TDS have to be ready to accept it. Part of the problem of stimulating technology utilization is to bring about this diffusion of readiness. When a TDS does not exist, the federal government may have to deliberately create one. One way of doing this is to set up a field agent system, as was done by the U.S. Department of Agriculture in the 1930's (*6*) to deliver R & D results into the hands of the farmers. Another approach is for the federal government to pay private companies to manufacture the product for a limited amount of time, in the belief that with this initial federal procurement a TDS will form itself. This seems to be the underlying theory behind federal technology demonstration projects such as that in the Solar Heating and Cooling Demonstration Act (*7*).

Defense Technology Delivery System and the Marketplace

Figure 1 illustrates the concept of a TDS in which the federal government provides the market for the application of R & D results. Under the stimulus of federal procurement, new technology is readily transferred from the R & D performers to the R & D users within that system. With the help of Armed Service procurement regulations or federal procurement regulations, a company which is a component of the system can acquire a working knowledge of the R & D results produced by others for the government, the costs being allowable as overhead charges to all the other federal R & D contracts the company has. The lending institutions provide the finances necessary for the functioning of the component while it awaits payments of its bills by the federal government.

The federal market can also lead indirectly to the creation of a civilian market for a new technology, when civilian needs are close to federal needs. For example, some well-known aircraft that are used by commercial airlines are adaptations of military aircraft.

Because of its capabilities in the most advanced technologies, it is not unusual for other federal agencies to choose the defense TDS to introduce a new technology to civilian applications, even though the federal government will not be the end user. This can cause some difficulties, because components of the defense TDS may not do business in the civilian marketplace. For example, a federal agency recently funded an aerospace company to develop a lightweight, efficient, two-way transceiver for use by police forces. Since the aerospace company was not in the consumer electronics business, it did not choose to commit its own resources to manufacturing and selling the transceiver to civilian police forces after completion of the R & D project. It sold the technology to a small private company formed for the purpose of making and selling these transceivers. The small company was underfinanced; it failed to make even its first payment to the aerospace company and went out of existence. In another example, the same agency developed a lightweight bulletproof jacket for police use by using the services of a nonprofit R & D corporation that did not traditionally manufacture or sell uniforms to civil police departments. The agency is continuing to fund the nonprofit corporation as a prime contractor to fabricate the jackets and distribute free samples to selected police departments. Regular clothing manufacturers are now being used as subcontractors.

It might be possible to avoid such potentially dead-ended situations if the federal government funded R & D performers that were components of both

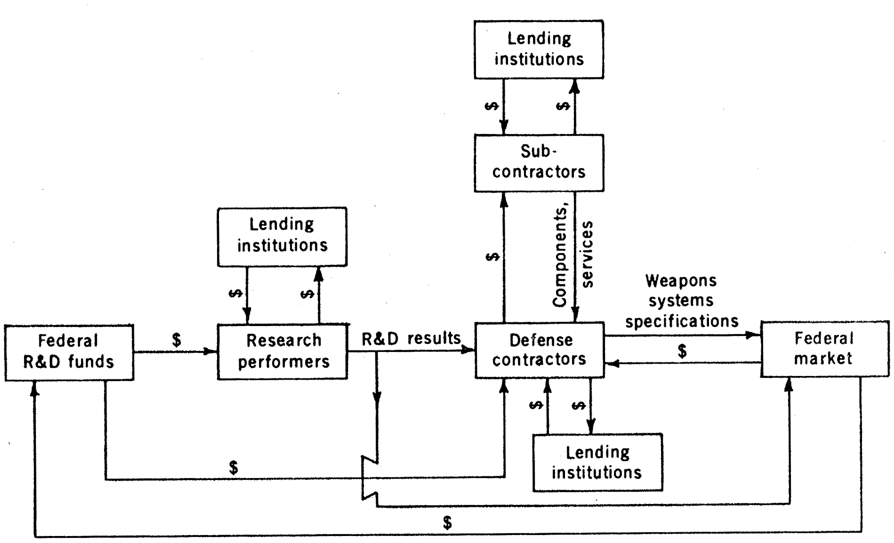

Fig. 1. A simplified diagram of the TDS for defense. It includes at least the following nonfederal institutional components: research performers, such as universities, nonprofit research institutes, and small R & D companies; defense contractors (who may also be research performers) and their suppliers; and financial institutions.

the defense and conventional delivery systems—that is, R & D performers that sold their products to both the federal and nonfederal markets.

Incentives for Technology Delivery Systems

Even when the federal government ensures that the R & D performer is a component of the appropriate TDS, the other components of the TDS may not necessarily be willing to play their part in bringing the new technology to the uncertain civilian marketplace in the form of new products, processes, and services. A number of different incentives may have to be used to achieve technology utilization because the incentive that stimulates one component of the TDS may well have no effect whatsoever on another component.

Many different incentives to stimulate the utilization of civilian oriented technology intended for the nonfederal market are currently being used by the different mission oriented federal agencies which fund civilian oriented R & D. Some of the incentives that may be applied to components of the TDS for the solar heating and cooling of homes are shown in Table 1. Some incentives cost more than others and some are more effective than others, but no systematic set of performance data has been compiled for the federal incentives currently in use. For this reason, the Experimental R & D Incentives Office in the Research Applications Directorate at the National Science Foundation funded a project in fiscal year 1974 for the purpose of collecting the performance data for these incentives from the appropriate federal agencies.

In the following sections I briefly review some of the incentives for technology utilization that are now being used by various federal agencies.

Procurement, Demonstration Projects, and Information Dissemination

Initial federal procurement of limited extent. The intent here is to get the product based on the new technology into production by private companies, in the hope that they will start selling the product to the public after termination of federal procurement. For this incentive to work, the product should not require much adaptation for the civilian marketplace, and there has to be a public desire to buy this product. The Law Enforcement Assistance Administration is one agency that uses this approach.

Federally funded demonstration projects. This is a popular and frequently used incentive for stimulating utilization of civilian oriented R & D results. An example is the recent "Operation Breakthrough" organized by the Department of Housing and Urban Development. The Bureau of Mines has used this incentive in the past and it is part of the ongoing activities of the Office of Coal Research. The purpose of such projects is to provide empirical data on production cost, performance, reliability, and public acceptance. If the private company carrying out the demonstration project is capable of subsequently manufacturing and selling the new product, process, or service to the public, the chances are much higher for technology utilization in the civilian marketplace. If the demonstration project does not stimulate all the components of the appropriate TDS, the new technology may see no further application after the demonstration. If the demonstration project is carried out by a component of the wrong TDS (for example, one that delivers only to the federal marketplace), then subsequent utilization in the civilian marketplace may not take place at all.

Table 1. A summary of the incentives for technology utilization now being used by different federal agencies, which may be applied to six of the components of the TDS for the solar heating and cooling of homes.

Private housing market (homeowners)
Information dissemination
Demonstration projects
Loan guarantees and loan insurance
Construction grants
Home builders and developers
Information dissemination
Demonstration projects
Limited federal procurement
Federally funded market research and testing
Federal cost sharing
Federal construction grants
Equipment manufacturers
Information dissemination
Exclusive licensing of federal patents
Demonstration projects
Limited federal procurement
Federal testing of new products
Federally funded market research and testing
Federal cost sharing
No-cost leasing of demonstration plants for manufacture
Lending institutions
Information dissemination
Loan guarantees and loan insurance
Local government codes and regulations
Information dissemination
Federal specifications
Architect engineering companies
Information dissemination
Demonstration projects
Limited federal procurement

Information dissemination. This is a necessary (but not sufficient) step to get the R & D performer to the potential user. The National Technical Information Service (NTIS) of the Department of Commerce has the responsibility for storage and retrieval of the final reports of federally funded R & D. Not only do the federal agencies funding R & D have to make sure that the NTIS gets their reports, but most of them also actively engage in their own information dissemination activities. For example, the Environmental Protection Agency, the Law Enforcement Assistance Administration, the Department of Transportation, and the Department of Agriculture have their own technology utilization divisions that publish and distribute documents and organize public workshops, short courses for industry, and cooperative R & D programs between the performers of research and the potential users of the results.

The information that is disseminated by the R & D performers must be converted into a working knowledge of the subject by the potential user, before technology utilization can begin to occur. This requires a substantial amount of time and money. An organization that wants to develop working knowledge of a new technology, starting with documentary information of the R & D results, must pay for the time that it takes its employees to read, understand, assimilate, and even test the new information. Unless it independently tests the new information there is reason to doubt whether it has actually acquired a working knowledge of the technology: a multitude of essential empirical facts may be missing from the documents because the R & D performers considered them too mundane or obvious (or even too subtle) to include them in the documentation. This is recognized by a company that licenses a patent. The licensing agreement usually calls for the technical services of the inventor, along with permission to use the patent.

Thus a company has to make a considerable investment in order to achieve a working knowledge of R & D results, even if it gets the documents containing the results at no cost. When it gets the information through licensing a patent, its investment of time and money is generally protected by the terms of the patent. When a company obtains federally funded R & D results, which are available to anyone for the asking, there is no such protection for the investment it has to make to convert this information into a working knowledge of the technology, nor for the substantially larger investment it has to make to convert this working knowledge into a new product, process, or service.

There are two well-recognized ways in which a company can avoid paying for converting federally funded R & D results into a working knowledge of a technology. One obvious way is for the company to get a government contract that will enable it to do the specific R & D in which it may have a future commercial interest. Another way is to obtain contracts to do R & D in general for the federal government. Both the Armed Services procurement regulations and the federal procurement regulations recognize the fact that it costs a company money to assimilate the results of R & D performed by another. Provided that the company's costs of doing this are normal and reasonable, they are allowable overhead costs which may be distributed over all the federal R & D contracts the company has. In contrast, a company that does not do R & D for the federal government must use its own resources to pay for the cost of converting federally funded R & D results into a working knowledge of the technology they describe.

The concept of federally funded field agents to bring the results of R & D to the potential user has a long distinguished history. The Department of Agriculture began using this approach before the era of mass communications (*6*). The PENN-TAP (technology assistance program) program in the State of Pennsylvania has been a successful effort of a similar nature directed toward industry in the state. However, to achieve the success of the Department of Agriculture's field agent program, a federal research administrator must contemplate a budget for the field agent system roughly equal in magnitude to his agency's R & D budget (*8*). This is difficult to accept, since it implies either a substantial increase in the budget for technology utilization, or a drastic decrease in the R & D budget with an accompanying diversion of funds from R & D to technology utilization efforts. What is needed, perhaps, is a low-cost modern equivalent of the field agent system.

Construction Grants and Federal Patents and Licenses

Construction grants. Federal grants are normally available only to universities and nonprofit organizations. Under special circumstances grants to private companies may be made, usually in conjunction with cost sharing by the company and the performance of a public service. For example, grants may be made by the Environmental Protection Agency to a private company for a water pollution control installation, provided it is the first of its kind so that the company is, in effect, carrying out a public demonstration of its technical feasibility. In this case it would be the combination of the grant and the federal water pollution control regulation that was the incentive to the utilization of R & D results on water pollution control, rather than the grant per se.

Federal patents and licenses to users. The federal government takes out patents largely as a defensive measure, to avoid paying royalties on patents resulting from R & D that it has paid for although the patents might have been applied for by others. Another reason is to make the patents available for use by the public on a nonexclusive license. Nonexclusive licenses for federal patents have been put to successful commercial use, but only after considerable federal investment has been made to remove practically all of the technical and economic risks. Examples are the patent on potato flakes by the Department of Agriculture and the patent on a fertilizer by the Tennessee Valley Authority (*9*). In the absence of such extensive federal investments in development, industry is reluctant to invest heavily in commercializing a federal patent on the basis of a nonexclusive license only. There has been a growing recognition of this fact and of the need to protect this investment in some way that will encourage private industry to make commercial use of federal patents. Only NASA at present has the statutory authority to grant exclusive licenses as an incentive to the commercial use of patents. An attempt to give exclusive licensing authority to the heads of other federal government agencies by a General Services Administration (GSA) patent policy has been struck down by a recent court ruling. The other provision in this GSA patent policy, that would give title to a patent to a research performer under certain circumstances even though the research was paid for by the federal government, is under challenge in the courts.

At present, federal policy on the ownership and licensing of patents is a weak incentive to the commercial utilization of federally funded R & D results, particularly since the only federal agency with statutory authority to give exclusive licenses on federal patents (that is, NASA) will not enforce the exclusivity against patent infringers.

Federal Cost Sharing and Leasing

Federal cost sharing with industry. This incentive to technology utilization is popular with federal research administrators for a variety of reasons and is being used by such agencies as the Maritime Administration and the Office of Coal Research, among others. Cost sharing by industry is regarded as a demonstration of industrial interest in a federally funded R & D program, and is therefore very useful in justifying a requested budget. Federal cost sharing is also a useful way of responding to pressures from industry and the general public. As an incentive to technology utilization, it is believed to raise the level of technical and economic risk that will be acceptable to a company that is trying to decide whether or not to exploit R & D results.

Cost sharing of a federal R & D contract can be a useful indicator of the intentions of industry regarding technology utilization. A company that accepts only a small proportion of the costs of the R & D, say about 5 percent, is unlikely to feel a great commitment to the subsequent exploitation of the R & D results, whereas a company accepting a high proportion of the costs, say about 80 percent, is certainly interested in using the results. However, situations in which very high proportions of the costs are borne by a company raise the legitimate question of whether that company was planning to go ahead on its own anyway without federal support, which could therefore be better used elsewhere. Thus one can deduce that between the two extremes there is a range of values indicating that a company is seriously interested in utilizing R & D results but is unlikely to proceed with the research on its own without the incentive of federal cost sharing. An attempt is being made by the Office of Experimental R & D

Incentives, in the Research Applications Directorate of the National Science Foundation, to find this critical range of cost sharing ratios through a retrospective study of the recent history of cost sharing R & D programs between the federal government and industry.

The same reasoning can be applied to cost sharing of pilot or demonstration projects, except that the costs for these projects are much higher than the costs for R & D alone. Here, the critical range of cost sharing ratios may well be different from that in R & D projects. It is also possible that this critical range will differ from one industry to another.

No-cost leasing of federal demonstration plants. When the capital investment required for a full-scale industrial plant is very high, the technical and economic uncertainties are great, and there is a pressing national need that must be met, the federal government may construct and lease such plants at no cost, for industry to operate. This is a very powerful incentive to the utilization of research results under conditions of great technological and economic uncertainty, and enormously facilitates subsequent investment by industry. This approach was used by the government during World War II, for example, when it constructed plants for the manufacture of synthetic rubber and penicillin.

Leasing of public sites. This lowers the economic risk to the technical innovator who wishes to use the results of R & D. Public lands are leased by the Department of the Interior, for example, to encourage the construction of experimental oil shale extraction plants and the construction of geothermal power plants.

Federal Testing, Performance Specifications, and Regulations

Government testing for new products and processes. Some federal laboratories, such as those in the National Bureau of Standards, test new products (for example, building industry products) and make the results of the tests available to industry and the public. This can be an incentive to the civilian acceptance of new products based on federally funded R & D.

Publication of government specifications. The publication of performance specifications can be an incentive to the utilization of a new technology, particularly if the specifications include the results of federally funded R & D. This approach, which is used extensively by the Department of Defense, exerts its strongest influence when it is coupled to a federal procurement. It can also indirectly affect the acceptance of a new technology in the civilian marketplace. For example, the existence of a federal government performance specification can influence a new technology's adoption into local ordinances, codes, or regulations. Such specifications can be especially important to the many state or local governments that have neither the extensive laboratory facilities that the federal government has, nor comparable resources for acceptance testing.

Federal regulations. Federal regulations, if they are based on the results of federally funded R & D, can be extremely powerful incentives to technology utilization. If they are not based on the results of R & D, then they can be harmful by specifying what may be technically impossible or unnecessarily demanding. In the latter case there may be extensive defensive litigation by industry instead of willing compliance. This has been observed by the Environmental Protection Agency in the area of water pollution control, and by the Department of Transportation in its efforts to regulate automobile exhaust emission and automobile safety.

Federally funded market research and testing. The demonstration of the existence and viability of a commercial market can be a powerful stimulus to private industry's converting the results of federally funded R & D into new products, processes, and services for the public. The Department of Agriculture used this approach to introduce potato flakes to the commercial market, and the Tennessee Valley Authority used it to bring about the commercial manufacture and sale of a new type of fertilizer (*9*).

This incentive has not been used as much as it could have been by the federal government to stimulate technology utilization for civilian purposes.

Loan Guarantees and Loan Insurance

These incentives have been widely used by the federal government to stimulate the availability of loans to the public for a variety of purposes. Through the Federal Housing Administration, these incentives have made loans available for the purchase of homes. The Small Business Administration has used them to encourage lending institutions to provide loans for small businesses.

In principle, these incentives are intended to raise the levels of risk that will be acceptable to the lending institutions. In practice, however, there is reason to doubt whether this is ever achieved. The primary decision on whether a particular loan should be made is the responsibility of the lending institution; after this decision has been made the federal agencies guarantee or insure part of the loan. Since only part of the loan is covered, the lending institutions are thereby encouraged to exercise their normal prudence.

The case for using such incentives for stimulating investment in technological innovation was made by the economist Kenneth Arrow (*10*) who concluded that for optimal allocation (of resources) to invention it would be necessary for the government or some other agency not governed by profit and loss criteria to finance research and inventions.

There is a growing belief that the federal incentives of loan guarantees or loan insurance should be used to stimulate investment in the high risk area of technological innovation. Two recently enacted laws (*11, 12*) are intended to provide federal loan guarantees in the areas of solar energy and geothermal energy, respectively. Since the normal sources of investment in technological innovation claim that their decisions are made solely on the merits of a particular case, it is possible that federal loan guarantees or loan insurance may not be as successful a stimulus in the high risk area of investment in technological innovation as it has been for housing. Investment in the utilization of the results of federally funded R & D also lacks the protection of private patent ownership or (with the exception of NASA) the limited protection of an exclusive license. "Seed money" investment in technological innovation is usually made in return for equity, in the expectation that the high return on equity will compensate for the high inherent risk of technological innovation.

Because of the well-founded reasons for and against the merits of federal loan guarantees or insurance as incentives for stimulating investment in technological innovation (and by inference, in technology utilization) a small-scale experimental verification would be extremely useful. The Experimental R & D Incentives Office of the National Science Foundation is now examining the merits of this approach.

Solar Heating and the Cooling of Homes

Using the concepts of a TDS, let use consider the role of incentives in stimulating public utilization of solar energy in the heating and cooling of homes. Most of the R & D in this area is federally funded and present plans do not call for the federal government to be the major market for the application of the R & D results.

Figure 2 shows the system for technology delivery to the market for privately owned homes, and shows the interactions among the different components of the TDS. For illustrative purposes only a few components are shown, so that the diagram hardly does justice to the enormity of the housing industry, its complex structure, and its fragmentation. Many other components, such as public utility companies, may belong in the system but are omitted for convenience (*13*).

Now let us consider the superposition of a federally funded R & D effort meant for solar energy on this TDS. It is illustrated in Fig. 3 by the addition of a component called "R & D performers for solar energy." For the R & D results to find their way from these performers to application in the private home market, it is necessary to bring about the interactions shown in Fig. 3. In order to stimulate these interactions it will be necessary to apply incentives to the appropriate components. Examples of incentives that the federal government may apply are illustrated in Fig. 4. Some of these incentives have very recently been incorporated into new laws, others are already being used by several federal agencies. The Solar Heating and Cooling Demonstration Act (*7*) is intended to stimulate acceptance by the private housing market. The loan guarantee provision of the Housing and Development Act of 1974 (*11*) was meant to encourage lending institutions to accept the additional cost of a solar heating and cooling system as part of the mortgage on a home. For local housing codes to accept solar heating and cooling systems, a model federal specification may be necessary. These examples are by no means exhaustive and additional incentives may have to be applied to the TDS to achieve the objective of widespread solar heating and cooling of homes. A recently passed law authorizes research on incentives to assure rapid utilization of solar energy for commercial and other purposes (*7*).

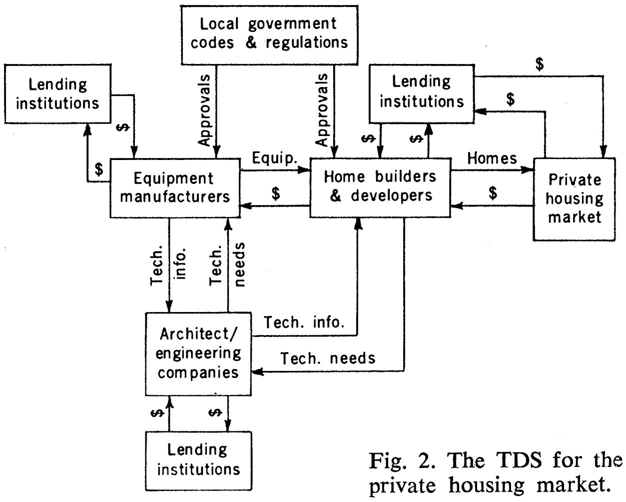

Fig. 2. The TDS for the private housing market.

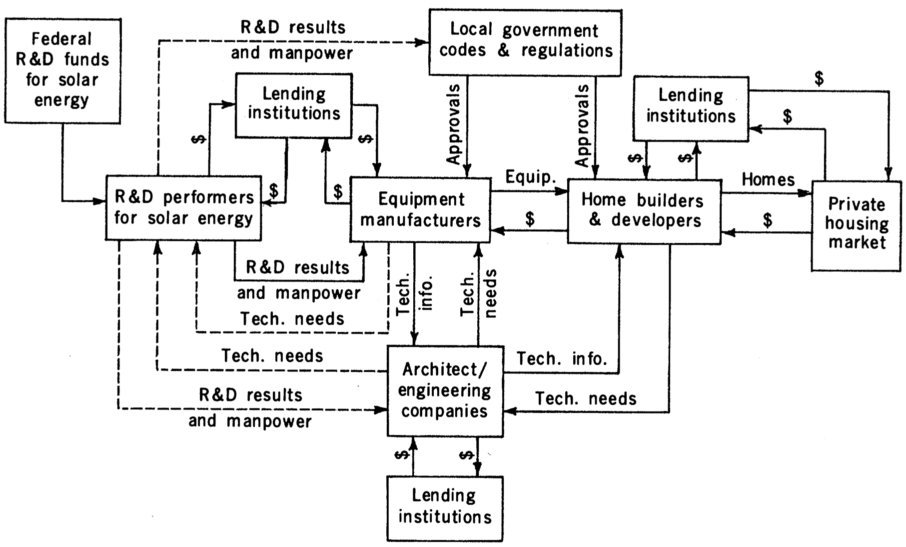

Fig. 3. The TDS for the private housing market showing the required interactions between the solar energy R & D performers and the other components. Broken lines indicate the linkages to be established or strengthened.

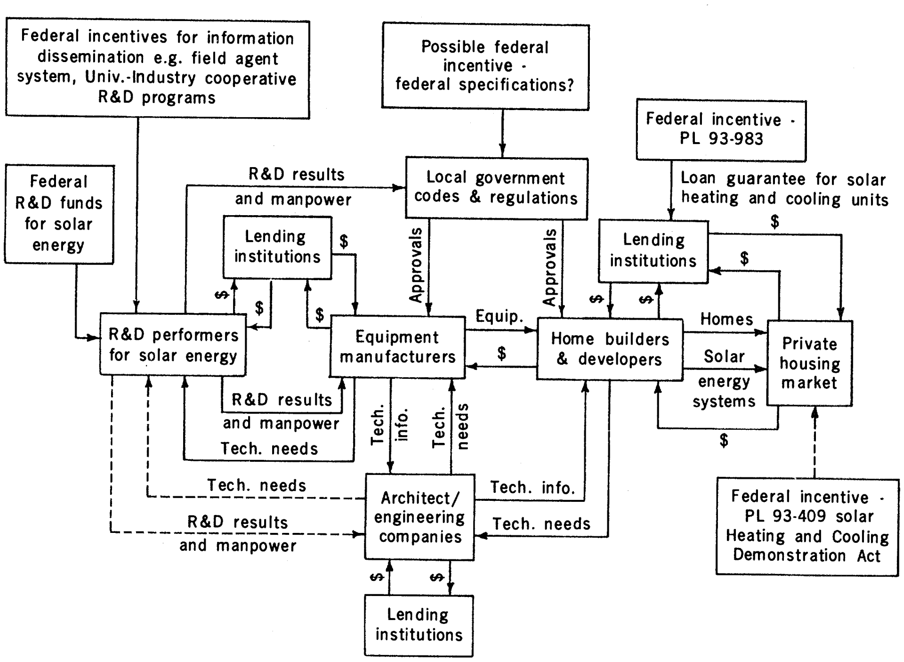

Fig. 4. The TDS for the private housing market showing examples of incentives for immediate use or consideration. Broken lines indicate linkages to be established or strengthened.

Summary

If the federal government is not going to be the major market for the application of federally funded R & D results, then the responsibility for bringing about technology utilization cannot be borne alone by the federal agency funding the R & D. That this problem is now being recognized is shown by the number of bills that were introduced in Congress in 1974, culminating in the Solar Heating and Cooling Act of 1974 (*7*).

An examination of the incentives for technology utilization in the conceptual framework of TDS (as shown in Fig. 4) reveals the following:

1) Incentives must be applied to each component of the TDS.

2) Different components in the TDS require different incentives.

3) Although information exists concerning a wide variety of incentives that are currently being used by various federal agencies to stimulate technology utilization, most of this information is in the form of raw data compiled by the respective agencies and a substantial effort will be required to collect, compile, and evaluate them.

4) All the components of a TDS must be activated if technology utilization is to occur on a self-sustaining basis. This makes experimental verification of a particular incentive on a particular component difficult.

5) A federal agency concerned with technology utilization can and should assume the responsibility for identifying all the components of the required TDS, devising incentives for each component and testing them to ensure their effectiveness. Where a TDS does not exist, the federal agency may have to assume the responsibility of creating one. The scope of this effort in many cases may transcend the present authority of the agency, and congressional action may be required to remedy this shortcoming.

References and Notes

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2. There are a number of excellent papers giving accounts of NASA's experiences in fostering civilian applications of NASA-generated technology. For example, see J. P. Kottonstette and J. J. Rusnik, *Res. Manage.* **16**, 24 (July 1973); J. G. Welles, "Contributions to technology and their transfer: a NASA experience," paper presented at the NATO Advanced Study Institute on Technology Transfer, Paris-Evry, France, 24 June to 6 July 1973; M. D. Robbins, *Mission Oriented R & D and the Advancement of Technology: The Impact of NASA Contributions; Final Report* (Univ. of Denver Research Institute, Denver, Colo., May 1972), vols. 1 and 2.
3. Technology transfer is sometimes used to describe information dissemination, but this is only a part of the technology transfer process.
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5. E. Wenk, Jr., chairman, "Priorities for research applicable to national needs" (Committee on Public Engineering Policy, National Academy of Engineering, Washington, D.C., 1973), p. 2.
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8. "*Agriculture—Environmental and Consumer Protection Appropriations," Hearings Before a Subcommittee of the Committee on Appropriations*, House of Representatives, 93rd Congress, 2nd Session (Government Printing Office, Washington, D.C., 1974), p. 231.
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10. K. J. Arrow, in *Rate and Direction of Inventive Activity* (Princeton Univ. Press, Princeton, N.J., 1962), p. 623.
11. The Housing and Community Development Act of 1974, PL 93-383.
12. The Geothermal Energy Research, Development, and Demonstration Act of 1974—PL 93-410. It provides a budget of $50 million for guaranteeing loans for the development of geothermal energy sources.
13. Many innovations have been introduced, disseminated, and applied over the past 100 years without any aid from federal agencies, although the Federal Housing Administration's home loans helped to create a larger potential market in the past few decades for these innovations, and the National Bureau of Standards' activities in testing new building industry products provided an additional incentive to the use of new products.

The Limitation of Human Population: A Natural History

The demographic transition of modern times is a return to a pattern familiar to our hunting ancestors.

Don E. Dumond

In demographic circles it has been commonly asserted that the long-term evolution of man was possible only because his high natural fertility permitted him to overcome the effects of an exceptionally heavy premodern mortality—mortality amounting to a loss before the age of reproduction of as much as 50 percent of all individuals born (*1–3*).

A corollary of this same viewpoint is the conclusion that the direction and degree of change in human population size has been governed in preindustrial eras solely by mortality. It is this preconception that has been largely responsible for "transition theory," which holds that the so-called demographic transition of modern times is the result of a new response toward reduction of growth induced by the rising standards of living and health that have followed upon the industrial and medical revolutions (*4*).

Recent years have seen attempts to modify these opinions, however, on the part of historical demographers [for example (*5–7*)], anthropologists [for example (*8–12*)], and others (*13*), who base their views upon various data from their respective disciplines. Unfortunately, discussion of the question is hampered on the one hand by the difficulty of constructing adequate demographic arguments from evidence of populations long dead (*14, 15*), and on the other by the fact that acceptable studies of hunter-gatherers or nonindustrial agricultural peoples are limited by the scarcity of such peoples still available for study whose lives have

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