

PASSIVE SOLAR ENERGY

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HEARING

BEFORE THE

SUBCOMMITTEE ON
OVERSIGHT AND INVESTIGATIONS
OF THE

COMMITTEE ON

INTERSTATE AND FOREIGN COMMERCE
HOUSE OF REPRESENTATIVES

NINETY-FIFTH CONGRESS

SECOND SESSION

AUGUST 11, 1978

Serial No. 95-153

Printed for the use of the
Committee on Interstate and Foreign Commerce



U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1979

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DOCUMENTS

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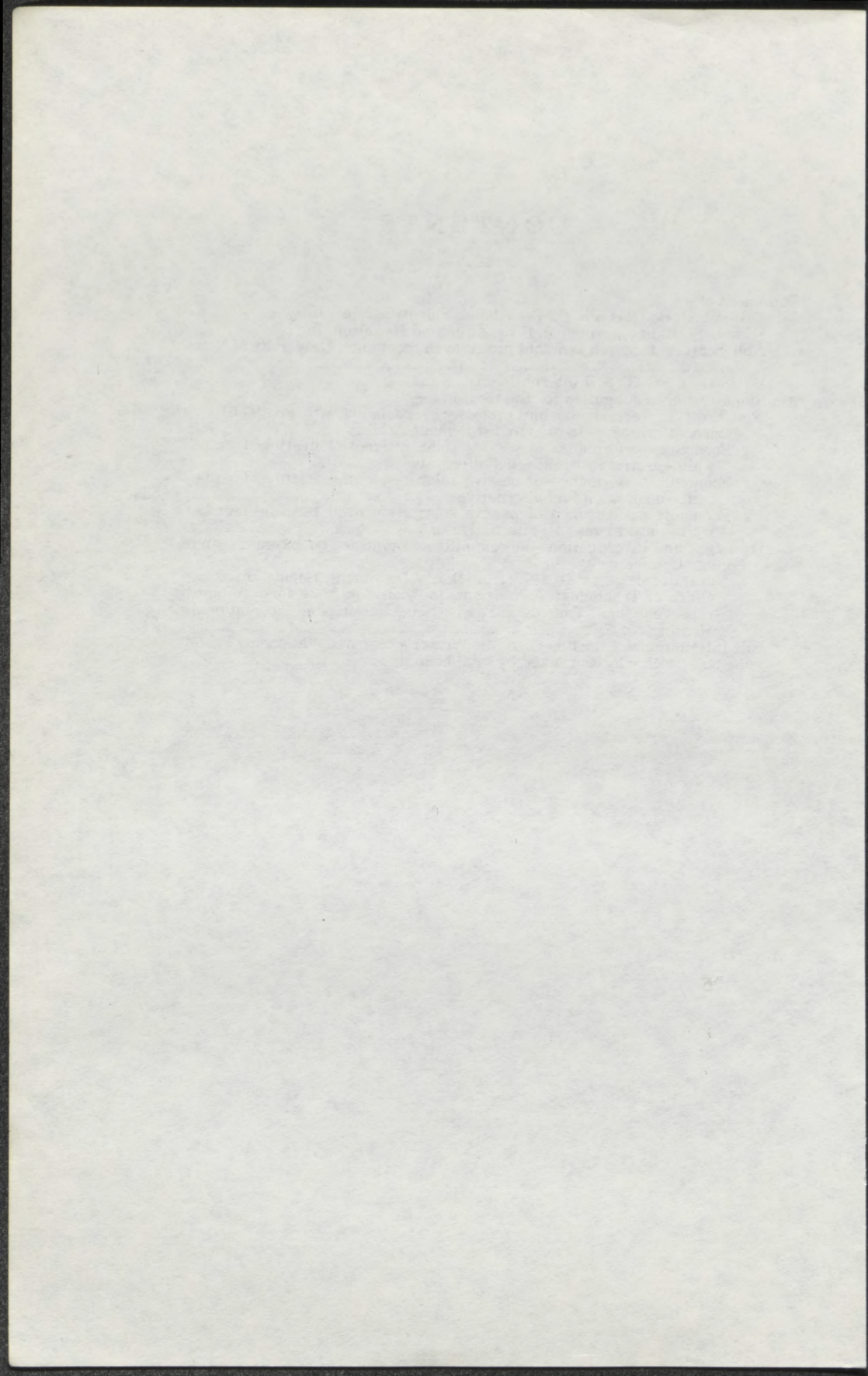
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CONTENTS

	Page
Statement of—	
Balcomb, J. Douglas, Ph. D., Los Alamos Scientific Laboratory	2, 47
Hirshberg, Alan S., principal, Booz, Allen and Hamilton, Inc	47, 59
Noll, Scott A., research assistant professor in economics, University of New Mexico	47
Witwer, Jeffrey G., SRI International	47, 55
Additional material submitted for the record by—	
Noll, Scott A., research assistant professor in economics, University of New Mexico, attachments to prepared statement (tables):	
Economic performance of passive solar residential heating Trombe wall—electric resistance fuel alternative	52
Economic performance of passive solar residential heating Trombe wall—heating oil fuel alternative	53
Economic performance of passive solar residential heating Trombe wall—natural gas fuel alternative	54
Oversight and Investigations Subcommittee, Committee on Interstate and Foreign Commerce:	
Letter dated August 10, 1978, from Daniel De Simone, Deputy Director, Office of Technology Assessment, to Chairman Moss forwarding a report entitled, "The Cost of Passive Solar Heating and Conventional Heating"	31
SRI International, attachment to Mr. Witwer's prepared statement, Table 1—Solar technologies ranked by total benefits	56



PASSIVE SOLAR ENERGY

FRIDAY, AUGUST 11, 1978

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON OVERSIGHT AND INVESTIGATIONS,
COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10 a.m. in room 2123 Rayburn House Office Building, Hon. John E. Moss (chairman) presiding.

Mr. Moss. The subcommittee today begins a series of hearings on solar energy and the contemporary consumer.

Today's hearing will focus on the simplest of the solar technologies, passive solar.

Unlike the more familiar pump-driven solar collectors and sun tracking mirror assemblies, passive solar is relatively straightforward and inexpensive. Typical passive solar installations involve greenhouses and orientation of substantial glazing to the south. To store solar heat during evening hours, thermal masses, such as masonry and containers of water, are often incorporated into passive building designs.

Federal policy toward passive solar energy is a puzzle. While the administration appears to support a vigorous solar program, passive solar occupies a barely perceptible niche in the DOE budget. By contrast, solar designers and a number of States, including California and New Mexico, give passive solar energy a central role in their own designs and programs.

Today the subcommittee will seek answers to the following questions:

What are the passive solar technologies?

What are their strengths and weaknesses?

Is the technology or elements of it ready for use by consumers?

To the extent that the technology is ready for consumer use, what Federal programs are necessary or appropriate?

To help us find the answers to these questions, the subcommittee will hear from J. Douglas Balcomb of the Los Alamos Scientific Laboratory. Dr. Balcomb is considered one of the leading solar theorists in the country.

Scott Noll of the University of New Mexico. Professor Noll has done unique work in the area of passive solar economics. He will be able to suggest whether a passive solar home or workplace is in our future.

Jeffrey G. Witwer of the Stanford Research Institute. Mr. Witwer was project leader of SRI's major study on solar energy. He can put a number of our current solar programs in context.

Alan Hirshberg of Booz, Allen, & Hamilton. Dr. Hirshberg will be able to provide a unique contribution with respect to the barriers which confront the commercialization of this technology. He will also suggest ways of overcoming these barriers.

Each of these men will help this subcommittee and the public understand this technology. This understanding will help us to frame appropriate Government policies toward this important solar opportunity.

At this time we would like to invite Dr. Balcomb of Los Alamos Scientific Laboratory to the table.

We are pleased to welcome you. If you have a statement we will be very happy to receive it.

STATEMENT OF J. DOUGLAS BALCOMB, Ph. D., LOS ALAMOS SCIENTIFIC LABORATORY

Dr. BALCOMB. Yes, sir. I appreciate the opportunity to testify on this important subject before the subcommittee. I am going to take a few minutes to explain the principles of passive design to the subcommittee, using a number of slides which I have brought, indicating which of these is ready for commercial use, the viability of these technologies in cold climates, the extent to which passive concepts can be incorporated into building designs which have already achieved consumer acceptance, and relating my own experience with living in a passive solar home.

If I could have the lights down please, I would like to try and convey some thought as to the principal concepts on which this technology rests. Of course, the major one is the fact that sunlight incident on the Earth is energy; sunlight carries energy with it. When that sunlight is absorbed on a surface such as the black surface inside a solar collector, it is converted to heat at that point. In much the same way when the Sun is incident through the window of a house, it heats the house directly with relatively high efficiency, since the transmission of double glazing is about 75 percent, and since the double glazing is a relatively good way of retaining heat within the house.

Another principle is the fact that the Sun angles work in our favor if we put this glazing on the south side of a building, because the Sun is low in the sky in the winter and shines predominantly on the south side. The Sun is high in the summer, shining on the east and west sides of the building and on the roof, but not on the south side. So by incorporating these simple ideas in the design of the building, one can get heat in the winter but not get heat in the summer by putting glazing on the south side. Such simple things as moving some windows in the design around from the north side to the south side can make major differences in the energy consumption of a building. Reorienting a building so that it faces properly can, by itself, make a building 10 degrees warmer in the winter and 10 degrees cooler in the summer.

The Los Alamos Scientific Laboratory, where I work, is involved in a program of evaluating passive solar, and we have been very impressed with our findings. We believe that passive solar is a very viable concept. This work is carried out for the U.S. Department of Energy.

I think it is important to define what I mean by this. A passive system is one in which the thermal energy flow is by natural means, that is by radiation, by conduction and by natural convection. This precludes the use of pumps or fans or other mechanical equipment to force energy to flow from one place to another.

I am going to illustrate passive systems by going through five different generic types. (See fig. 1.) The first is a direct gain approach, which is what I alluded to earlier: simply having windows on the south side of the building, the sun shining through those windows heating the building directly during the day, and if there is excess energy, then that can be stored by heating the floor, back walls, other areas within the building carrying that heat over for use at night. An extremely simple concept.

Houses such as this one in New Mexico (see fig. 2) are now being built with a lot of glass on the south, with the east, west, and north sides having few windows, and an additional mass built into the house. (See fig. 3.) This particular house in Hinesburg, Vt., has double glazing, consisting of two sheets of glass in one place, and two sheets of an acrylic in other places, and within the house a very massive central fireplace wall, which is the principal heat storage, so that the Sun which shines in during the day offsets all of the daytime heating loads. (See fig. 4.) The mass of the building heats up, and this keeps it warm at night. All of these buildings are very well insulated, so that their heat load is relatively small to begin with, and a majority of the remaining heat load is supplied by passive solar gains.

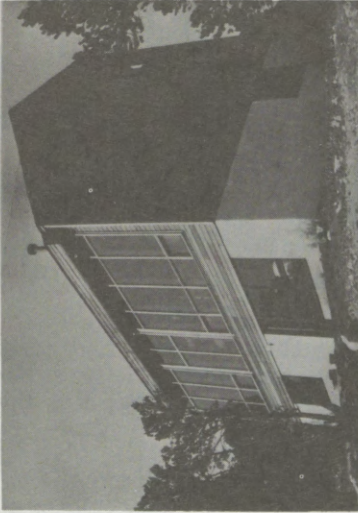


FIGURE 2

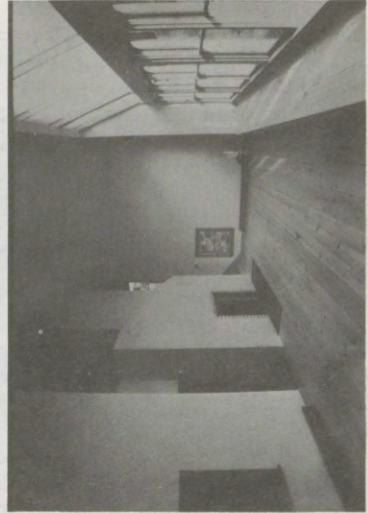


FIGURE 4

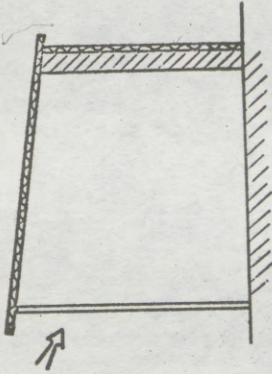


FIGURE 1

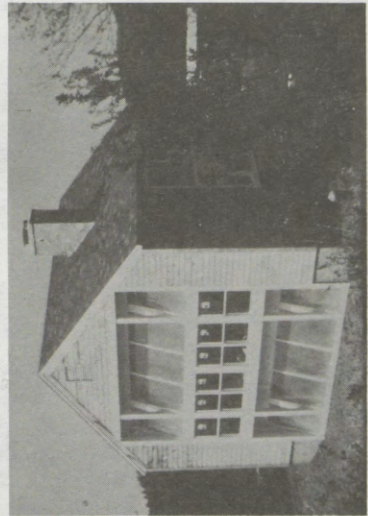


FIGURE 3

This is the Wallassy School in Liverpool, England (see fig. 5), built in 1962. It is about 50-percent solar heated. It is a very large structure with a double glazed south solar wall. The rest of the structure is concrete walls, ceiling, floor, insulated on the outside with 5 inches of styrofoam. The building was supplied with an auxiliary heating system when it was built. It has only been turned on once since 1962. The rest of the heat, the other 50 percent, comes from the lights in the building and from the students. It has been thoroughly evaluated, and is about 50 percent solar heated at a location of 53 degrees north latitude, rather near the seawall, in Liverpool, England.

This house in Cody, Wyo. (see fig. 6), is in a very cold climate. It uses the direct gain approach. You can see the windows on the south side and above. (See fig. 7.) This picture taken inside the house shows a relatively warm, cozy atmosphere. All of the backup heating in the house is from that central fireplace, burning about 1.5 cords of wood in the winter; the predominant heat energy comes directly from the Sun.

At MIT (see fig. 8), an experimental project funded by the Department of Energy is looking into a passive design which can be incorporated into multilevel structures. Although this small test house is just one story, it could be stacked because the method of energy gain and heat storage is light enough in weight to be used in multilevel structures.

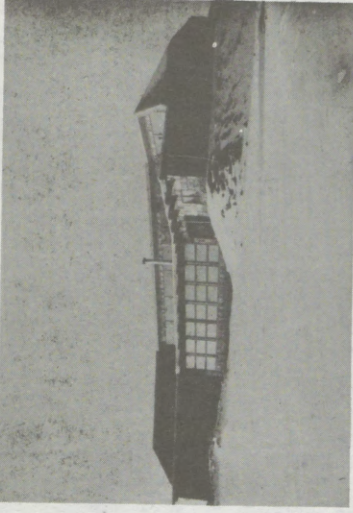


FIGURE 6

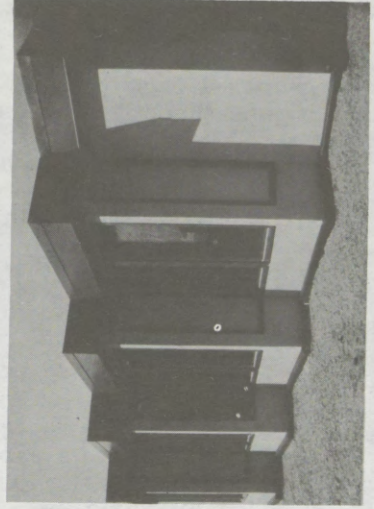


FIGURE 8

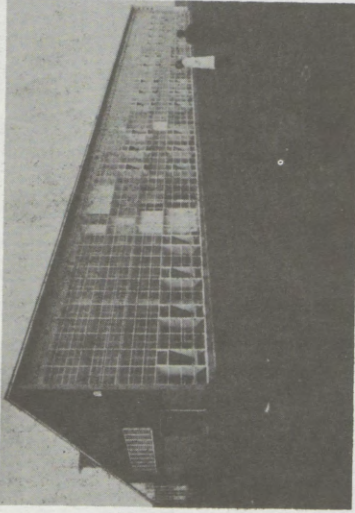


FIGURE 5



FIGURE 7

This shot inside shows (see fig. 9) that a special venetian blind like device just inside the window reflects the sunlight up onto the ceiling, and there the heat is stored in a special ceiling tile. The tile is a special design which stores a great deal of heat in a small mass. The Sun also provides natural lighting within the building, which saves additional energy.

This building in New Hampshire (see fig. 10) is one of the national heating and cooling demonstration project buildings. It is the most cost effective of the commercial demonstration projects. It is a large warehouse, in which the south side of the warehouse has been double glazed with an acrylic fiberglass material which allows the Sun to be transmitted into the space. The principal heat storage in the warehouse is in the materials which are located within the warehouse. It is a very cost-effective approach.

In Portland, Oreg. (see fig. 11), there is now under construction a whole subdivision of passive solar homes of the direct gain type, which utilize frame construction, south glazing in vertical south walls and clerestory windows which can be seen on the right. It is a hybrid system, hybrid in the sense that there is a fan in the house which takes air out of the building during the day, runs it through a rock bed—a box of rocks underneath the floor—where the heat is stored for later retrieval in the evening. They are expecting that house will be about 50 percent solar heated in Portland, Oreg. There is a frontal view of one of the houses. (See fig. 12.) There are 15 houses in this subdivision.

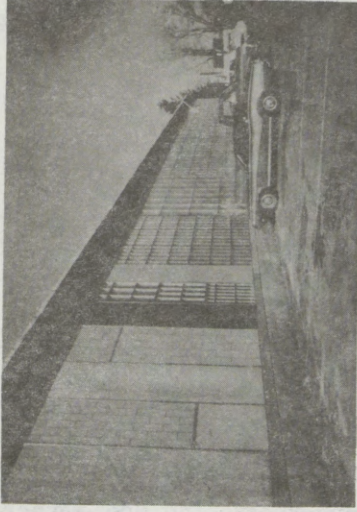


FIGURE 10



FIGURE 12

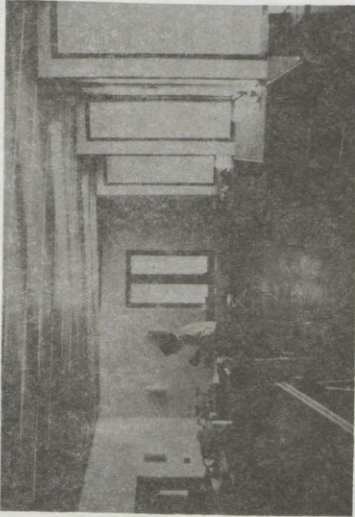


FIGURE 9

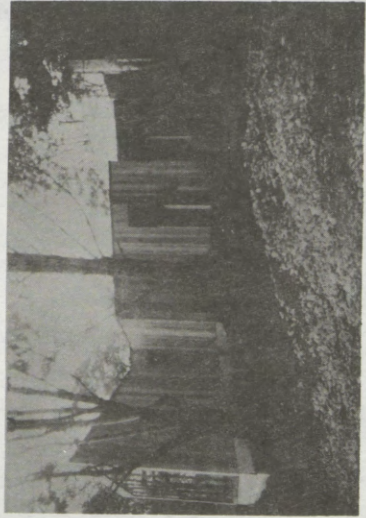


FIGURE 11

Some of these buildings use back clerestory windows so that the Sun and heat energy is admitted to the back part of the building as well as through the south wall.

This restaurant in Cambridge, Mass. (see fig. 13), allows the light and heat to come through the roof using a lattice structure to prevent direct glare in the building, providing a nice environment, uniform lighting, and effective solar heating.

This is a State office building in Taos, N. Mex. (see fig. 14), a relatively square single story structure which has 13 rows of clerestory windows across the roof admitting light onto water barrels which are located up in the ceiling space. The Sun shines on those barrels of water, where the energy is stored. There is also an automatic system to provide a uniform natural daylighting within the space, tremendously reducing the electrical energy requirements for lights.

This is an airport in Aspen, Colo. (see fig. 15), which has a direct gain supplying about 50 percent of the energy. The sunlight is admitted through the sections you see on the roof, and also through all of the south wall sections. It incorporates two novel types of moveable insulation, by which I mean the glazed walls and roof sections roof are open to admit the Sun during the day, but then the insulation is put in place—by an automatic passive system—to preclude heat loss at night. And this is a very desirable feature, especially in an extremely cold climate like Aspen, Colo.

The next type of design is a thermal storage wall which overcomes some problems with the direct gain approach. There may be too much light and heat in a direct-gain room. There may be some overheating during the day, if one attempts to achieve a very high fraction of heat from the Sun. The thermal storage wall gets around some of those drawbacks. By placing the heat storage mass immediately behind the glazing, as shown in this diagram, the heat is absorbed directly on the outside surface of the wall. Heat loss is reduced by double glazing located outside the wall. The heat diffuses by conduction through the wall and is transmitted to the room by radiation and natural convection.

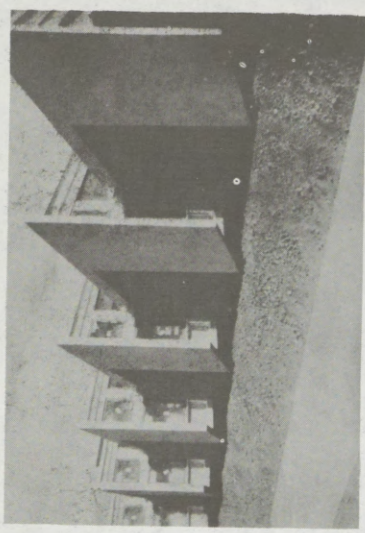


FIGURE 14

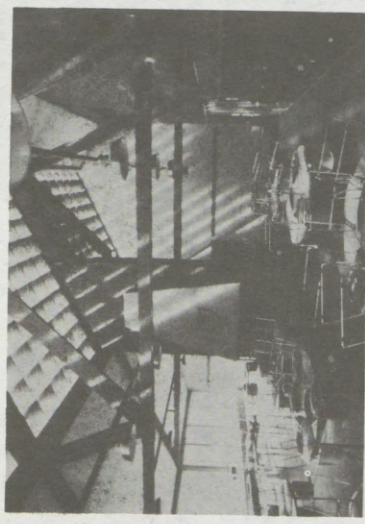


FIGURE 13

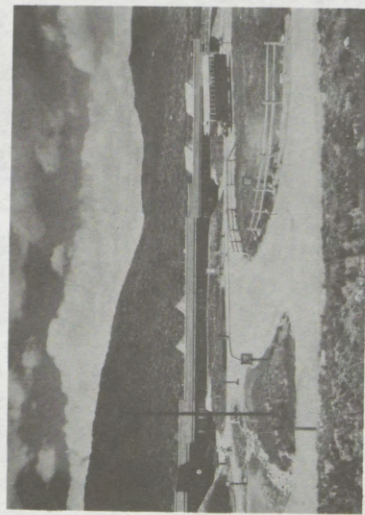


FIGURE 15

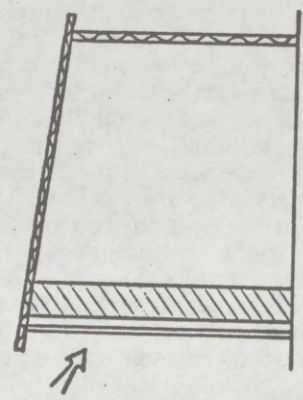


FIGURE 16

The wall can be made of concrete, as was done in this house in the Pyrenees section of southern France. (See fig. 17) This house was designed by Felix Trombe and Jacques Michel. This whole concept now bears the name of "Trombe wall," named after Felix Trombe who popularized the idea. This is a 2-foot thick solid concrete wall behind double glazing, a relatively simple structure. It has been evaluated over a long period of time, and provides 70 percent of the heat in a totally passive sense to this small structure high in the mountains of southern France.

The Trombe wall idea has been incorporated into this two story Trombe wall in Los Alamos, N. Mex. (see fig. 18), designed and built by a friend, Bruce Hunn. The wall in this case is made of concrete block, in which the holes were filled with mortar as the wall was being made. The wall is 12 feet wide and 27 feet high and provides 60 percent of the heat energy to this house in the relatively cold climate of northern New Mexico. A photo inside the house shows the interior of the wall on your right. (See fig. 19) You can see that the concrete block, which has an attractive appearance, makes an attractive internal wall. It very effectively heats this room as a large radiant panel. The wall is very evident and pleasurable when one is in the room on a cold winter evening.

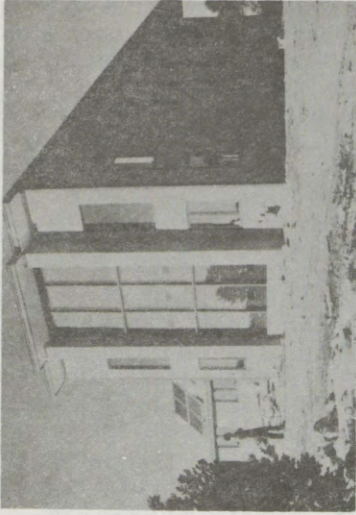


FIGURE 18

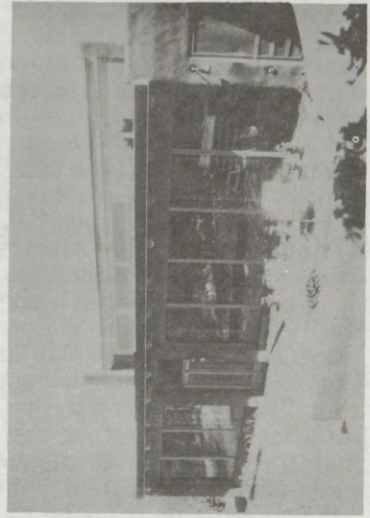


FIGURE 20

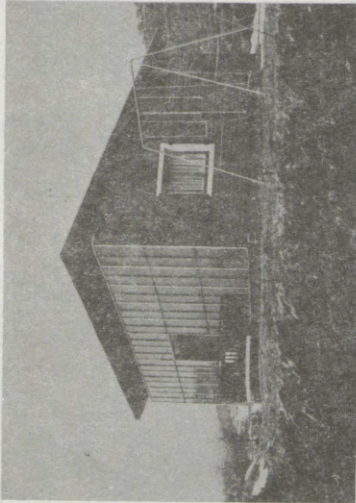


FIGURE 17

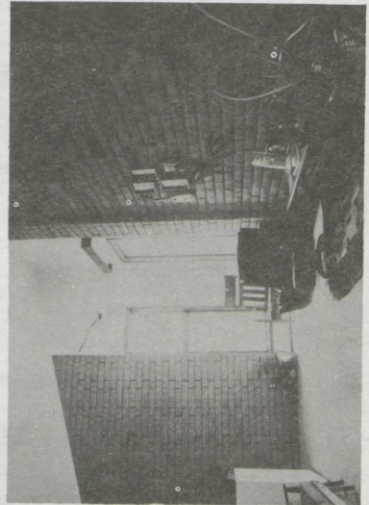


FIGURE 19

A neighbor of mine has built this house in Santa Fe, N. Mex. (See fig. 20.) It has a Trombe wall across the south side. To provide visual relief to the solid masonry wall, windows extend through the wall. This picture (see fig. 21), taken on the inside, shows how one of those windows looks. There is a single pane of glazing in that window, and then an additional two sheets of glass clear across the south side, so that this house uses both direct gain through the windows and the Trombe wall approach.

The same idea was incorporated 2 years earlier in this architect's house in Princeton, N.J. (See fig. 22.)

The house is of a frame construction, except for a 15-inch thick Trombe wall on the south side which is covered with double glazing over the whole south side. You can barely see the six windows piercing the concrete wall. There is a very evident greenhouse section over a quarter of the south wall. The house is about 80 percent solar heated through the last three winters. It is in the old section of Princeton, N.J., fitting rather nicely into the environment there, with minimum problems due to the large old trees that are around.

This house is in Star Tannery, Va. (see fig. 23), near Winchester. It is of frame construction, built by a small company that has gone into business with this particular technology. It uses water in containers rather than concrete for the thermal storage wall. (See fig. 24.) If we go inside and have a look, you can see that it appears like a normal wall. However, behind the sheetrock there are fiberglass boxes filled with water on which the Sun shines. That is the thermal storage, a very effective design.

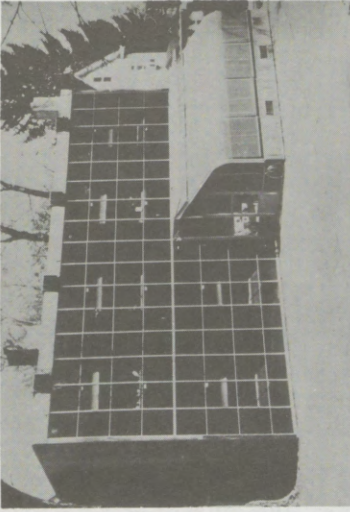


FIGURE 22



FIGURE 24



FIGURE 21

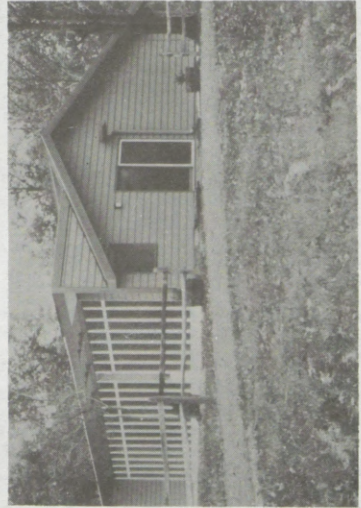


FIGURE 23

In Aspen, Colo. (see fig. 25), this house also uses the water wall idea. The water is in large cylinders standing on the floor behind the glazing. You can barely see them here, but if we go inside (see fig. 26), you can see the large cylinders. They are made of fiberglass, and are filled with water, painted a dark color on the outside, and they are the thermal storage.

Combining these concepts—direct gain and the thermal storage wall—has been done in this warehouse and office building at the Benedictine Monastery in Pecos, N. Mex. (See fig. 27.) The building is 7,700 square feet in a climate where it gets down to 14° below in the winter. The principal part of the building, the warehouse, is direct gain and has no auxiliary heating at all. The minimum temperature in that warehouse in the winter is in the low 40's, but it is typically in the mid 50's most of the time in the winter. The office space out front does have electrical resistance, auxiliary heating, and also a water wall. Their total heating bill for an entire winter for the auxiliary heating was \$80.

The third concept is the solar greenhouse approach, in which a direct gain room is located on the south side of the building (see fig. 28), which is frequently used as a greenhouse. Sometimes I refer to this as an attached sunspace, with the living part of the house on the north side separated from the sunspace by a mass wall. It works much as the Trombe wall system does with the heat diffusing through the wall heating the north rooms, but you get a greenhouse space as part of the home as a very attractive side benefit.



FIGURE 25

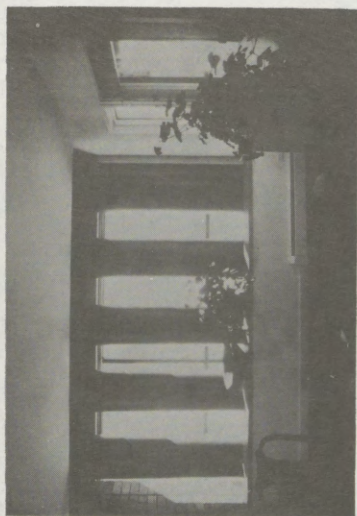


FIGURE 26

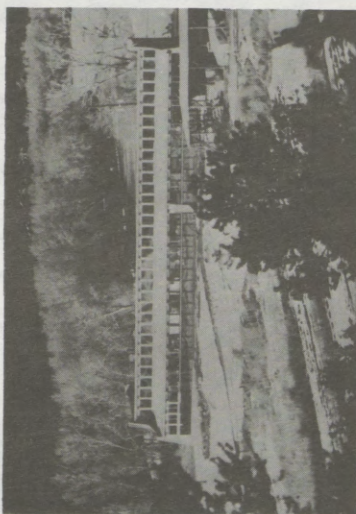


FIGURE 27

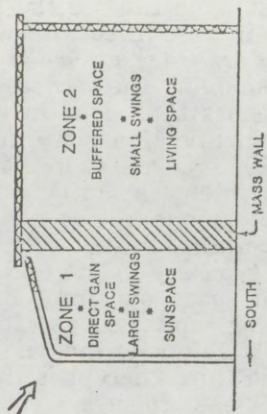


FIGURE 28

This is my own home in Santa Fe, N. Mex. (See fig. 29.) It is a two-story attached greenhouse structure. I will come back to it in a moment and explain a little bit more about how it works.

The attached solar greenhouse has become a tremendously viable and effective concept for retrofitting or upgrading an existing building with a solar addition. This is one such retrofit greenhouse built by the solar sustenance project in New Mexico. (See fig. 30.) The owner of the house and his friends, with the help of this project, built this little greenhouse out of 2-x-4s and fiberglass at a total cost of about \$2.50 per square foot for the materials. It extends the growing season from 2 or 3 months in this high, cold mountain valley to 10 months. It requires no auxiliary heating at all, never freezes in the greenhouse, and provides substantial additional heat to the house. It is one of the most exciting types of passive retrofit ideas.

Such greenhouses are now being built in many styles in many places within the United States. This rather elegant fiberglass and wood greenhouse is being custom designed for homeowners in Denver, Colo. (See fig. 31.)

Here we have an interesting situation, a retrofit solar greenhouse on a house which was already fitted for an active solar system. (See fig. 32.) You can see the air-heating collectors on the roof, which do a good job of heating the house, but then they added the solar greenhouse on the south side.

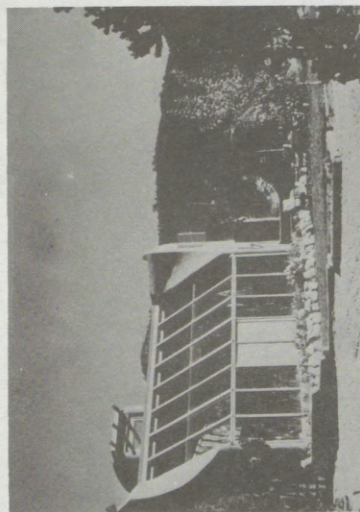


FIGURE 29

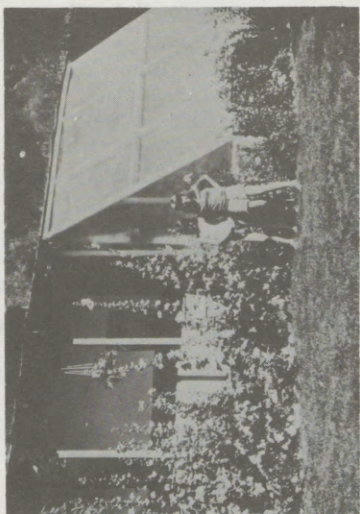


FIGURE 30

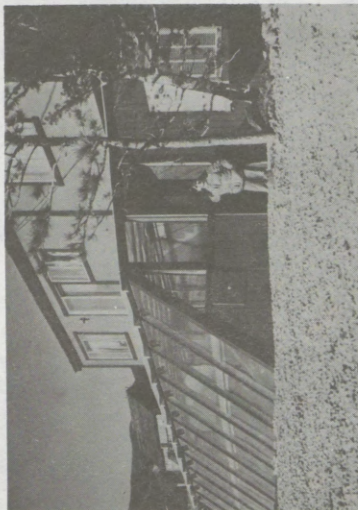


FIGURE 31

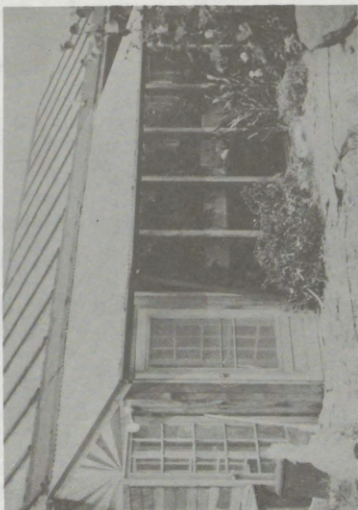


FIGURE 32

You can see from the plants inside that it is a pretty good environment for them as well as providing some additional heat to the house. (See fig. 33.)

Solar greenhouses take all sorts of shapes and sizes. This one was added onto an existing house. (See fig. 34.) The garage was already there and a relatively square greenhouse was added. This is an addition that my son and I built on our previous home in Los Alamos, N. Mex. It worked very well, providing a delightful environment added to the house.

Thermal mass can be built into the roof. I would call this a thermal storage roof approach. (See fig. 35.) It works quite differently because of the different Sun angles, and does require some form of moveable insulation.

The thermal storage roof idea has been popularized by this home in California. (See fig. 36.) One principal advantage to this is that it provides not only for winter passive solar heating, but it provides for a natural means of air-conditioning by tuning the house so that it loses heat effectively at night, and then does not absorb heat in the day. In this case the mass for thermal storage is in water bags in the roof section of the house, and so it is called a roof pond approach.



FIGURE 33

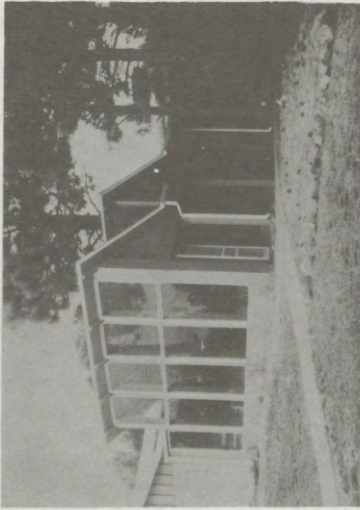


FIGURE 34

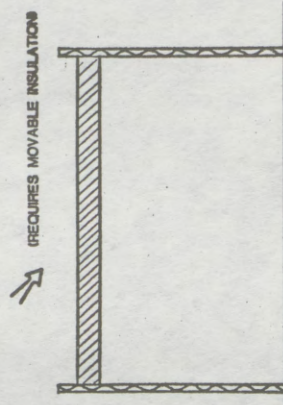


FIGURE 35

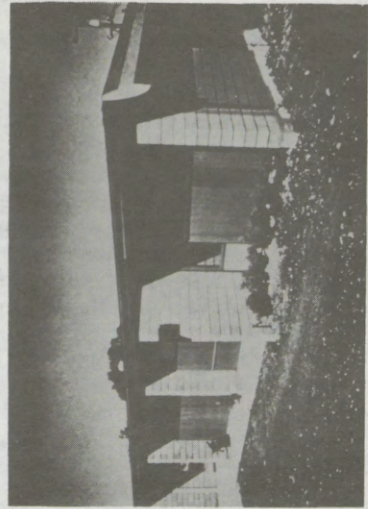


FIGURE 36

Los Alamos is experimenting with a thermal storage roof. It is quite different in detail, providing only for passive solar heating. This is a mobile/modular house, a double wide unit, in which the thermal storage is in water bags, located in the ceiling section. Sunlight is admitted onto them through four clerestory windows. There is a system of movable insulation located within the clerestory space. Heat is transferred down into the house by radiation from the ceiling. It seems to be working quite well, although we do not yet have a full winter's data on its operation.

The last type I will describe is a convective loop. (See fig. 38.) It is most akin to normal active solar systems in that there is a separate solar collector and a separate thermal storage, but if the collector is placed below the thermal storage, then heat can be transferred by natural circulation of the working fluid and pumps or fans are not required.

The classic thermosiphon water heater is in this category. It can also be used in an air system such as this one in Albuquerque, N. Mex. (see fig. 39), which has been in existence several years now. You can see the collectors as the lowest element in the system on the south side. The rock bed thermal storage is under the porch behind and above the collectors, and heat is transferred from one to the other by natural convection.

A more recent building which is being instrumented and evaluated by LASL is this house in Sante Fe (see fig. 40), which has a 600-square-foot air heating collector system and a rock bed located behind and above it. We have been interested to note that the collection efficiency of this system is a little above 30 percent, which is typical of the performance one expects from a good well-designed active air system, so that there does not seem to be any performance penalty due to the passive approach.

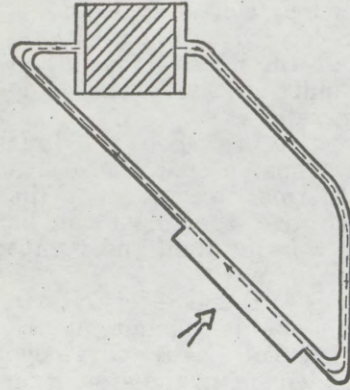


FIGURE 38

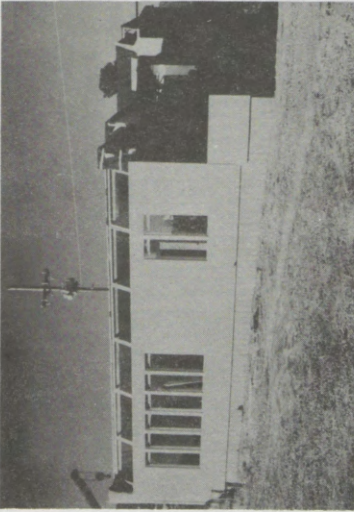


FIGURE 37

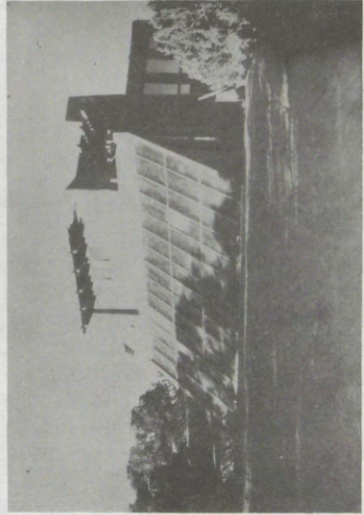


FIGURE 40

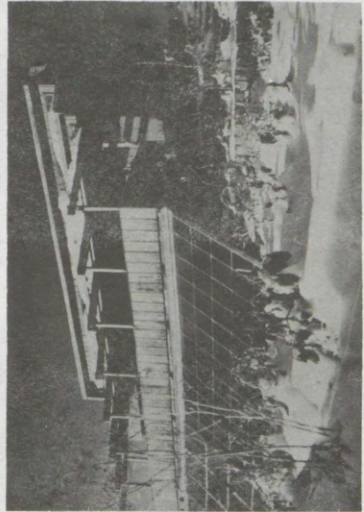


FIGURE 39

I will now go back to my house (see fig. 41) and describe a bit about the experience of living in a passive solar home. It has been quite a remarkable and revealing experience for my family. There it is in the winter. I showed it before in the summer. In order to indicate how the house works, I will show you the floor plan. (See fig. 42.) The house has a triangular two-story greenhouse on the south side as seen in the lower section on this diagram. Behind the greenhouse there is a mass wall. Because it is a native material in our area we use an earth brick (adobe) although in other locales the mass wall might equally be made of concrete or fieldstone or any masonry material.

The living part of the house wraps around and is on the north side of that wall, sharing that mass wall with the greenhouse. The outside north wall is simply an 8-inch frame wall with full insulation, very well insulated, so that the thermal mass is within the thermal envelope of the building. The Sun shines into the greenhouse, heats the floor, and back wall of the greenhouse, and that provides the principal heating in the home.

Here is a picture taken inside the greenhouse. (See fig. 43.) Although we have temperatures well below freezing throughout the winter, the low temperature in this greenhouse was 46 degrees last winter, and we are able to grow all sorts of plants and our table vegetables right through the winter.

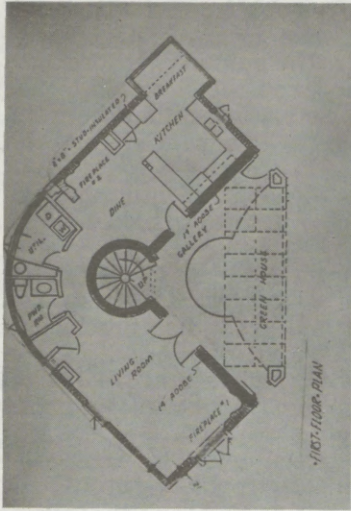


FIGURE 42



FIGURE 44

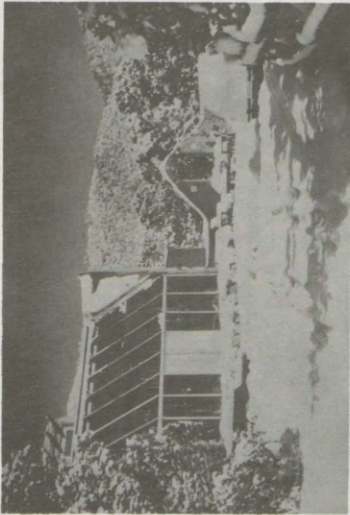


FIGURE 41



FIGURE 43

Inside the living part of the house (see fig. 44) we are shielded from the direct effects of the Sun, and there is a very stable internal environment which tends to stay in the range between 70° and 75° in the summer, and 65° and 70° in the winter. We do have auxiliary heating, an electric baseboard system, and a couple of fireplaces. We burned about half a cord of firewood last winter, and our total auxiliary electric heating, which is separately metered, was 857 kilowatt-hours, costing a total of \$38 in this 2,000-square foot house. (See fig. 45.) It is a very comfortable environment, and we have noticed that even on days like this, when it is cold and gray, the greenhouse always warms up during the day, because there is still appreciable energy in that cold, gray light, and it is very efficiently and effectively collected by the passive system.

This is another picture inside the greenhouse. (See fig. 46.) You can see the adobe wall behind, and the fact that we are able to grow many delightful plants in this space. It adds a delightful ambience to the home, with good smells and a little bit of added humidity, which is a good thing in our climate in the winter. In the summer we simply open up vents and windows, and it does not overheat.

I am going to conclude with a very simple indication of the relative costs of different design approaches. (See fig. 47.) I put these costs in terms of dollars per square foot of solar collection area. The direct gain approach has quite a wide range, and the costs can be very low.

For example, if in the design you simply put windows on the southside of the house instead of the north side, that can be done at no added cost. However, as one attempts to design to achieve a major fraction of the heat from the Sun, additional mass must be added to the house, and this cost must be charged against the solar system. The add-on cost of direct gain is in the range of \$2 to \$11 per square foot.

The thermal storage wall approach is somewhat more expensive. It is really a Cadillac of a solar heating system, with very good thermal comfort characteristics, ranges in cost from \$8 to \$18 per square foot. It is hard to figure costs for an attached sunspace because the sunspace itself has value, but if we attempt to do this in a fair way, I estimate the range to be \$5 to \$15 per square foot. My own solar greenhouse fell at the low end of that range.

The thermal storage roof approach has been used less than the others. One must be careful to have a reliable movable insulation system, and this may be costly. The range here is based on very little experience and is \$10 to \$25 per square foot of collection area.

The convection loop also has a very small experience basis. There are only a few such buildings. They have been done on a do-it-yourself basis at cost from \$5 to \$8 per square foot.

How do such systems work in various climates? I have taken an example case, a Trombe wall, in which the area of the Trombe wall is equal to one-third of the floor area of the house. It is an 18-inch wall, with a double glass cover, and has provision for some means of insulation at night, then hold the temperatures inside are held within a comfort range of 70° to 80° F. We have computed using a very detailed computer code, the amount of auxiliary energy which would be required in this building in different climates.

We have validated these computer codes against data. (See fig. 48.) We have taken measurements in test rooms in Los Alamos and instrumented buildings, and we are quite sure this is an accurate approach. It is done based on an hour-by-hour simulation through the entire year. We have done it for many climates, and here are some of the results for four particular locations. The Sun would provide 80 percent of the heat for the building in Albuquerque, N. Mex., 65 percent in Washington, D.C., 62 percent in Seattle, Wash.

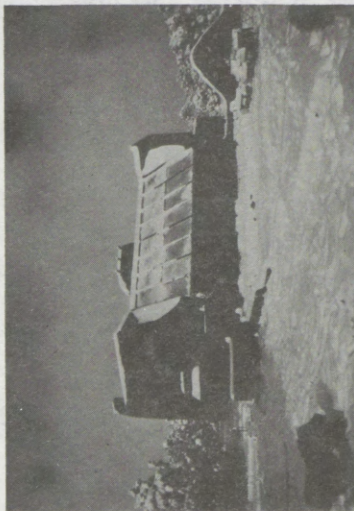


FIGURE 45

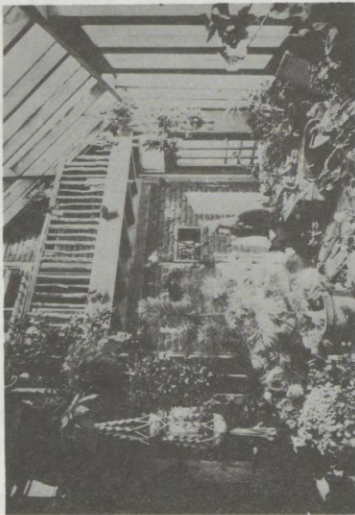


FIGURE 46

PASSIVE SYSTEM COSTS
(DOLLARS PER SQ FT OF SOLAR COLLECTION AREA)

THERMAL STORAGE WALL	2-11
DIRECT GAIN	8-18
ATTACHED SUNSPACE	5-15
THERMAL STORAGE ROOF	10-25
CONVECTIVE LOOP	5-8

FIGURE 47

SOLAR PERCENTAGE OF TOTAL HEATING REQUIREMENT

ALBUQUERQUE, NEW MEXICO	80% ^a
WASHINGTON, D.C.	65%
SEATTLE, WASHINGTON	62%
MADISON, WISCONSIN	50%

FIGURE 48

Now the climate in all of those three cities is similar in terms of the normal heating load. The performance is better in Albuquerque because there is more sun there, but the performance is still credible in the other two locations.

In a much colder climate in Madison, Wis., it would provide 50 percent of the total energy. In fact, the energy yield in Madison is higher than the others because the total heating load is somewhat greater. This is not an optimized design. It is just the identical house placed in these various climates.

A very simple look at the economics. (See fig. 49.) If I multiply the cost of the system, estimated at \$12 per square foot installed, times an 11 percent factor to account for 10 percent capital recovery, amortizing the cost of the initial investment, plus 1 percent operation and maintenance per year, and divide by the annual energy savings, I can compute an apparent cost of solar heat. In cents per kilowatt-hour, this ranges from 4.3 in Madison, Wisconsin, up to 6.1 in Washington, D.C. or Seattle. Then you need to compare that against the cost of some other way of heating the house, and in all of these locations except Seattle, this would be cost-effective. The reason is that electricity costs less than 2 cents per kilowatt-hour in Seattle, because of the hydro resource in that locale. This gives you a feeling of what this additional first cost in the building implies in terms of a cost of solar heating. Scott Noll will go into the economics in more detail in his presentation.

	ANNUAL ENERGY SAVING BTU/SQ FT	COST OF SOLAR HEAT* ¢/kwhr
ALBUQUERQUE, NM	94,000	4.7
WASHINGTON, D.C.	74,000	6.1
SEATTLE, WA	74,000	6.1
MADISON, WI	106,000	4.3

*System Cost = 12\$/sq ft, installed
 Capital Recovery Factor = 10%
 Operation & Maintenance = 1% per year

FIGURE 49

I would like, time permitting, to address one other aspect. There are a number of myths about passive solar heating which have been promulgated, and I would like to indicate that I believe that most of these are erroneous. One is that it will only work in the sunny Southwest. I think my examples show that in fact it will work throughout quite a range of climates.

The second myth is that you have to change your living standard in order to accept this passive solar heat, that it is cold and it cycles a lot and it is hot sometimes.

Correctly designed, a passive solar home can be fully as comfortable as a conventionally heated house, if you use an auxiliary heating system to provide 20 percent or more of the heat energy, and if you correctly design the house. I can testify to that from my own experience, in which the house is normally stable within a range of plus or minus 2° or 3° degrees year round.

The third myth is that these approaches are only suitable for new construction. In fact, about half to a third of all of the passive buildings in this country are retrofits, that is, they are additions to existing buildings. There are a number of very good passive retrofit approaches. I have indicated some, but there are others. That concludes my statement.

Mr. GORE [presiding]. Thank you very much, Dr. Balcomb. Counsel is recognized for questions.

Mr. GREENE. Thank you, Mr. Chairman.

Dr. Balcomb, could you describe for us the universe of buildings to which this technology may be applicable.

Dr. BALCOMB. We know now that it is applicable to small structures, that is residences, townhouses, small commercial buildings, and we pretty well know how to do that today. We know that larger structures have different problems, because a lot of their heat comes from internal generation, from lights, from people, from equipment within the space, and the management of that energy poses some more difficult problems. I do not think any such building is ever wholly passive, but this is not to say that passive approaches might not be applied. But certainly in small structures, which are dominant energy users in this country, passive can be applied.

Mr. GREENE. If we begin to incorporate passive principles into this class of buildings you have described, what are the likely savings in oil or natural gas that we might be able to expect during the reasonably foreseeable future?

Dr. BALCOMB. This depends entirely on how much impact you believe the passive technology will have, and what the penetration of the market is. It is difficult to forecast that, but let me suppose that in the 22 years between now and the year 2000, of approximately 40 million new buildings which are to be constructed we assume that 10 million are passive solar buildings. We do not build very many today, but perhaps 50 percent of the new construction would be passive in the year 2000 for an average of 25 percent.

Assume that we also retrofit an additional 10 million buildings from the existing stock of 70 million buildings, for a total of 20 million passive solar buildings, and that each one saves 25 million Btu per year. Then multiplying those two together, we can see that the total annual savings is one-half of 1 quad per year, that is one-half of 10^{15} to Btu per year. Translated to effective savings in natural gas this would represent a saving of about 1 trillion cubic feet per year in the year 2000, or one-half of 1 million barrels of oil per day.

Mr. GREENE. One-half million per day?

Dr. BALCOMB. Yes.

Mr. GREENE. Dr. Balcomb, one of the things which has caused a bit of confusion I think here in the Congress has been the question of what is passive. Let me direct your attention to sheets of paper

before you which are taken from the Senate Finance Committee Report on the Energy Production and Conservation Tax Incentive Act. As you are no doubt aware, the National Energy Act proposed by the President includes certain tax credits for solar devices, and this reflects a statement of the appropriate Senate committee on that credit.

Down in the next to the last full paragraph it states that passive solar is included.

However, expenditures for materials and components which will serve a significant structural function in the dwelling (for example, extra-thick walls) would not be eligible for the credit.

Would that exclude any of the technologies which you have discussed with us today?

Dr. BALCOMB. It would, yes, largely exclude most of the things that I have talked about. One of the principal advantages of these technologies is there is a shared function. The wall is serving not only a structural function, it is serving a heat storage function, and this aids the economics a great deal. I read this paragraph as excluding such dual function use. I believe that a great deal of the add-on cost of passive designs is in such materials and components which are serving structural functions in most of the designs I showed, and that the effect of this would be to largely exclude passive systems except for a few designs.

Mr. GREENE. Do you regard this effort to divide solar technologies between active and passive as appropriate Federal policy at this point?

Dr. BALCOMB. No; I don't. I think to have such a provision would discriminate against passive systems. I don't believe that this is an appropriate Federal policy. If we are to have a tax credit, I would like to see it administered in such a way that it would apply equally to passive systems and active systems.

Mr. GREENE. Generally my understanding is that per Btu an active system is somewhat, and perhaps substantially more expensive than a passive system for the same amount of heat.

Is that a correct understanding?

Dr. BALCOMB. That is our experience, yes.

The costs of most active systems which are being installed around the country today are in the range of \$20 to \$30 per square foot for residences, and \$40 per square foot and up in commercial installations.

So, they are substantially more expensive.

Mr. GREENE. So, to the extent that a consumer would rely upon the signals contained in the tax code he might be misguided or guided to a less efficacious purchase if he follows this provision of law, is that correct?

Dr. BALCOMB. Yes.

Mr. GREENE. To put the economics of this particular technology in some greater context, let me put before you a report prepared for the subcommittee by the Office of Technology Assessment.

[The report referred to follows:]

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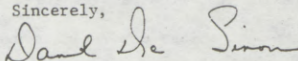
August 10, 1978

Honorable John E. Moss
Chairman, Subcommittee on Oversight
and Investigation
Committee on Interstate and Foreign
Affairs
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

Thank you for your letter of August 10, 1978, requesting additional information about passive solar economics. It is my understanding from discussions with our Energy Program staff that you would like this material for hearings you are holding on August 11, 1978. Governor Peterson is out of town this week, so I have asked our Energy Program staff to prepare a response based on our recently completed solar study and other ongoing work. A copy of this material is enclosed with this letter. I hope this information will be useful to you, and I appreciate your interest in OTA.

Sincerely,



Daniel De Simone
Deputy Director

Enclosure

THE COST OF PASSIVE SOLAR HEATING AND CONVENTIONAL HEATING

Introduction and Summary

This paper presents a comparison of the cost of passive solar heating with the cost of heat from conventional sources. It is based on material used in preparation of the OTA solar study¹ and on material subsequently gathered for use in other OTA studies now being completed. The cost of useful heat provided to a house by a passive solar heating system is compared with the cost of heat provided by a conventional fossil fuel system or electricity taking into account the conversion efficiency and ownership costs of the conventional end-use equipment. This material shows that the cost of heat from commercially installed passive solar heating systems ranges from \$6.50-\$16.50 per million Btu and is as low as \$2.00 per million Btu if based only on the cost of new materials for owner-installed systems. This compares with present costs of \$4.80-\$16.00 per million Btu for typical furnaces, baseboard heaters, or heat pumps using gas, oil, or electricity. It thus appears that passive solar heating can be competitive with conventional home heating today.

Cost of Heat from Passive Solar Heating Systems

The cost of heat from passive solar heating systems depends on the system and the costing methodology used. As an example, consider the role of windows in a residential building. Most houses have windows on their south wall which were installed purely for the light and view they provide. If they are relatively unshaded inside and out they will also reduce the heating bill slightly, and it can be argued that this heat is free since the windows were installed for other reasons. Likewise, some of the windows that would ordinarily be placed on the north wall of a new house can be put in the south wall instead reducing the heat needed, again at no additional cost. Alternatively, the cost of this heat could be computed based on the difference between the cost of a blank wall and the

cost of the wall containing windows. Greenhouses attached to residences can be treated in the same manner in that the cost of heat they provide depends on how the intrinsic value of the greenhouse is treated.

Passive systems may change the appearance of a house which further complicates the costing. For example, the addition of slightly larger windows to increase heat gain may generally be welcomed, but if they are too large then glare becomes a problem. Inclusion of a greenhouse in a home can be a distinct plus if the owners enjoy plants and indoor gardening, but would not be a strong selling point for others. The use of massive construction to provide heat storage in the winter and retention of coolness in the summer can be done in tasteful ways which should add to the value of the home, but floors which are used for thermal storage lose efficiency if carpeted. Thus a passive solar heating system may increase the value of a home both for its value as a heating system and for other intrinsic reasons if it is aesthetically accepted, but a poorly designed system could decrease a home's intrinsic value even if it does allow a reduction in heating costs.

These subjective reasons make it difficult to estimate the total costs of passive systems. Installation and performance costs of a number of existing passive solar heating installations are available, however, and are shown in Table 1. The incremental costs shown are based on estimates made by the designer, builder or owner of each house. These estimates represent the increase in construction cost which is attributed to the passive solar heating system. The glazing areas shown are based on the net glazing area which does not include the window frames. The "heat supplied to the house" represents an engineering estimate of the heat supplied which is actually useful in the house and does not include heat which must be vented by opening windows on mild days. Fuel consumption data was used in some cases to check the consistency of the estimate, and there

TABLE 1
COST AND PERFORMANCE FOR SEVERAL PASSIVE SOLAR HEATING INSTALLATIONS

Installation	% Solar Heating	Incremental Cost of Passive System		Heat Supplied to House (millions of Btus)	Cost of Heat* (\$/Million Btu)	System Description
		(Total Cost in \$)	(\$/ft ² of glazing)			
Lasar House New Milford, Conn.	70	2,000-3,000	4.00-6.00			200ft ² direct gain, 175 ft ² Trombe wall and 125 ft ² greenhouse
Crosley House Royal Oak, Md.	50-60	2,500	7.15	38	6.50	200 ft ² Trombe wall and 150 ft ² direct gain
Kelbaugh House Princeton, N.J.	75-80	9,000	11.25	88	10.20	535 ft ² Trombe wall, 200 ft ² greenhouse and 65 ft ² direct gain
Balcomb House Santa Fe, N.M.	80+	6,900	16.90	80	8.60	409 ft ² greenhouse and rock-bed storage
1st Village #3 Santa Fe, N.M.		7,148	17.50	80	8.90	179 ft ² Trombe wall, 144 ft ² direct gain and 86 ft ² greenhouse
1st Village #4 Santa Fe, N.E.		9,969	23.00	86	11.60	246 ft ² direct gain and 188 ft ² Trombe wall
Benedictine Monastery Pecos, N.M.	95	8,500	6.30			920 ft ² direct gain and 426 ft ² drumwall
Hunn House Los Alamos, N.M.	60	5,436	12.40	32.4	16.80	300 ft ² Trombe wall and 140 ft ² direct gain with rock-bed storage
Hay House Atascadero, Ca.	100	7,530	6.85			1100 ft ² roof pond provides all heating and cooling

TABLE 1 Continued

Installation	% Solar Heating	Incremental Materials Cost of a Passive System (Total Cost (\$/ft ² of glazing) in \$)	Heat Supplied to House (millions of Btus)	Cost of Heat* (\$/Million Btu)	System Description
RETROFIT GREENHOUSES					
Egri House Taos, N.M.	80	1,500	20	7.50	160 ft ² greenhouse retrofit to adobe house
Solar Sustenance Project		395-652	15-20	2.00- 4.30	Cost range for 12 retrofit greenhouses built throughout the Southwest
Griffin House Santa Fe, N.M.	24	127	22	0.58	Retrofit Greenhouse built largely from recycled materials
*Cost of Heat is computed assuming a 10% annual capital charge					

Note: This table is based on material from the following sources:

Office of Technology Assessment, "Application of Solar Technology to Today's Energy Needs", July, 1977 (prepublication draft) and June, 1978 (final).

William A. Shurcliff, Solar Heated Buildings of North America: 120 Outstanding Examples, Brick House Publishing Co., Harrisville, New Hampshire 03450, 1978.

R. P. Stromberg and S. O. Woodall, "Passive Solar Buildings: A Compilation of Data and Results", Sandia Laboratories SAND77-1204, August, 1977.

John Hayes and Drew Gillett, editors, "Proceedings of the Conference on Energy-Conserving Solar-Heated Greenhouses", Marlboro College, Marlboro, Vt. 05344, November 19-20, 1977.

Andrew M. Shapiro, "The Crosley's House", Solar Age, November, 1977, p. 31.

Steve Lasar, private communication.

Bruce Hunn, private communication.

Wayne Nichols, private communication.

appears to be considerable variation in the quality of the estimates shown. The "cost of heat supplied to the house" was computed from the heat supplied and the system cost by assuming a 10 percent annual charge on the system cost. The basis for this charge is described in detail in Chapter IX of an OTA study.² Since these costs do not account for any 'intrinsic' value for the passive system, the estimates shown may be high.

The systems shown in the top portion of Table 1 all provide over 50 percent of the heat for a house. Smaller systems will typically do this at a lower unit cost since they require less storage. The ranges of cost and performance shown result from different climates, different system designs, and from the fact that it is generally more expensive to build a system which "fits" an expensive house than it is to build a system appropriate for an inexpensive house.

Passive heating systems, especially those which do not include the use of active controls and supplementary storage systems, are particularly attractive to individuals who wish to build their own house, or retrofit a solar system to an existing home. The retrofit greenhouse additions listed at the bottom of Table 1 illustrate the extremely low costs which can be achieved by the homeowner who is willing to provide his own labor. These additions are quite simple to build and can be installed by people with limited construction skills.

Cost of Heat from Fossil Fuels and Electricity

Table 2 shows the cost of fuels and heat supplied to houses from a variety of present and future sources of fossil fuel and from electricity. The residential fuel prices shown were assembled from a variety of sources as described below and reflect ranges of present or expected costs for fuel delivered to a residential customer. The cost of heat delivered to the house is the cost of a million Btu's of heat delivered to the interior of the house after considering the furnace losses and ownership costs. It is thus comparable to the corresponding

column of Table 1. It is expected that for modest increases in initial cost, the efficiency of conventional furnaces and heat pumps will be improved in the future. The third column of Table 2 shows cost estimates for this case. The basis for the energy prices shown and the equipment efficiencies and costs used in preparing Table 2 are discussed below.

Gas: Natural gas prices to residential customers range from about \$2.00 per million Btu in the Southwest to about \$4.00 per million Btu in New England³ where the gas is piped in over long distances or derived from supplemental sources such as LNG or SNG from naphtha. The average wellhead price of interstate gas is \$0.93 per million Btu and the average price to gas distributors is \$1.54 per million⁴ Btu. Comparable averages for intrastate gas are not known, but typical new contracts are \$1.50-\$2.00 per million Btu at the wellhead. The synthetic gas prices were compiled from a variety of sources for use in the OTA solar study.¹ The LNG prices are based on current and pending LNG projects⁵ and prices for "exotic sources" are based on the OTA study of Devonian shale⁶ and a recent presentation by Henry Linden of the Gas Research Institute.⁷

Oil: A substantial quantity of fuel oil is imported and apparently is not affected by crude oil entitlements, so increasing the price of U.S. crude oil to world levels would not result in a large increase in the price of fuel oil. The delivered price of \$0.50/gallon corresponds to \$21.00/bbl.

Electricity: Some electricity is available to residential users at prices below 3¢/kWh, especially in the Northwest, and some is sold for more than 5¢/kWh, principally in the Northeast, but 3-5¢/kWh is typical for much of the country. The delivered price of electricity from new capacity was calculated for the four cities treated in the OTA solar study and was within a few mills of 7¢/kWh for each city.

Equipment Efficiency: Different values of efficiency were used for gas furnaces, oil furnaces, baseboard electric heaters, and heat pumps. The typical seasonal

TABLE 2
COST OF HEAT SUPPLIED TO HOUSES FROM
FOSSIL FUELS AND ELECTRICITY

	Residential Fuel Prices (\$/Million Btu)	Cost of Heat Supplied to Houses (\$/Million Btu)	Cost of Heat Supplied to Housing Using Improved Equipment (\$/Million Btu)
Natural Gas	2.00- 4.00	4.80- 8.10	4.40- 6.90
Intrastate Gas	2.50- 4.00	5.60- 8.10	5.00- 6.90
Synthetic Gas	4.00- 8.00	8.10-14.80	6.90-11.90
--projection cited most often	5.00	9.80	8.20
LNG	3.00- 6.10	6.50-11.60	5.70- 9.50
Natural gas from "exotic" sources (Tight formations, Devonian shale, geopressured aquifers)	3.25- 7.50	6.90-14.00	6.00-11.30
Oil (@50c/gallon)	3.60	9.50	8.00
Baseboard electric heaters			
-electricity @ 3-5c/kWh	8.79-14.65	10.10-16.00	NA
-electricity @ marginal cost of 7c/kWh	20.51	21.80	NA
Heat pumps			
-electricity @ 3-5c/kWh	8.79-14.65	8.30-12.10	7.00- 9.90
-electricity @ marginal cost of 7c/kWh	20.51	15.80	12.90

efficiency of gas furnaces is 60% and it may be possible to improve this to 80% at a cost of about \$400/furnace. The seasonal efficiency of typical oil furnaces is 50% and it may be possible to improve this to 70% for \$500/furnace. Baseboard electric heaters are essentially 100% efficient. Typical heat pumps have a seasonal performance factor of 1.55 (an efficiency of 155%) in a 5,000 degree-day climate.⁸ The "improved" heat pump installation was assumed to have a seasonal performance of 2.0 at no additional cost. This corresponds to the performance of some installations today, and it seems likely that typical performance can be increased to approach this level.

Equipment Costs: The ownership costs of conventional systems are due to the initial cost, the annual maintenance cost, and (for heat pumps which have a typical lifetime of only 10 years) a pro-rated replacement cost. These costs were all based on the OTA solar study.¹

FOOTNOTES

¹Office of Technology Assessment, "Application of Solar Technology to Today's Energy Needs," June 1978.

²Office of Technology Assessment, "Application of Solar Technology to Today's Energy Needs," July 1977 (prepublication draft).

³American Gas Association, "Quarterly Report of Gas Industry Operations--Fourth Quarter 1977."

⁴Department of Energy, April 1978.

⁵American Gas Association, "Gas Supply Review," June 1978.

⁶Office of Technology Assessment, "Status Report on the Gas Potential from Devonian Shales of the Appalachian Basin," November 1977.

⁷Henry Linden, presentation at the Second Aspen Energy Conference, July 1978.

⁸Westinghouse Electric Corporation, "Load and Use Characteristics of Electric Heat Pumps in Single-Family Residences," EPRI EA-793, Project 432-1 Final Report, June 1978.

Mr. GREENE. I would direct your particular attention to the last three pages of that document which contains two tables. The first table provides an estimate in the penultimate column of the cost of heat per million Btu by certain types of systems that has been experienced in particular homes, passive solar homes in the country.

Those range generally from about \$6.50 to about \$16.80 per million Btu. Then flipping over to the last page, which indicates the cost of delivered heat using traditional energy technologies and traditional energy sources, I note that with respect to some forms of natural gas, those forms of natural gas I suppose which are at the end of the pipeline, passive solar is to some degree already competitive with those forms of heat, that with respect to some of the new sources of natural gas, new sources of energy which we have been asked as a Congress and as a country to fund, such as liquid natural gas and exotic source natural gas, that passive solar may in fact be a better buy.

Would that be your assessment as well?

Dr. BALCOMB. Yes, I think the numbers in these tables are reasonable estimates. The heat supplied to the house in some cases may be slightly high. In a few cases, I think I would quarrel with the costs, but not in a substantial way.

I think the cost of heat as it is computed here looks reasonable and in line with my experience. I am familiar with almost all of these houses to one extent or another.

I think that you have a reasonable estimate here. The cost of the last one is probably estimated much too low, unless he was able to achieve a cost of 50 cents per square foot of glazing by recycling materials and not counting his labor into the cost.

Mr. GREENE. But generally, as you review these economic figures, would I be correct in assuming that if we, as a society, were to make decisions based upon the economics of new sources of energy, that it is very likely that many of us have passively heated solar homes in our futures?

Dr. BALCOMB. I think that would be a logical decision, based on what I know about how buildings work and how the Sun works in them.

I am concerned a bit about the incentives which are proposed because we have in those incentives selected a particular technology and chosen to say that is good, and something else that we may not even know about today isn't therefore included.

I would prefer a system in which the reward is directly related to the objective. In this case, the objective is not to promote passive solar or active solar as such. The objective is to save energy in buildings. Any approach which achieves this objective should be subject to the reward.

I think it would be possible to devise an equitable system of energy quotas or energy budgets for buildings in which a monthly energy budget is determined for each building based on its size and whether the building is old or is new construction, and the actual climate for that month.

The building occupant would be penalized for energy use over and above this quota by a steeply increasing fuel charge and rewarded for living within the budget by a low base rate.

These budgets would be administered through the existing system of utility billings and energy usage measured with existing utility meters.

I think it would be necessary to couple such an incentive system with an associated program of low interest loans made available to help in upgrading our existing stock of buildings and offsetting the additional first cost in new construction.

I would prefer such an approach to selecting any particular technology to achieve the desired end.

Mr. GREENE. Dr. Balcomb, if you were advising a consumer who had asked you: "describe for me the least that I can do from a passive solar perspective, through to the most that I can do, and in that description indicate how much energy one might save," what would you say?

Dr. BALCOMB. One of the nice things about this technology is that you can do a little bit or a lot. Simply cutting an additional window in the south side of the house, double glazing it, providing perhaps for some means of reducing heat losses at night and suitable shade to keep the Sun out in the summer, will provide a little bit of useful heat.

In fact, as we try to get a higher and higher fraction of the energy from the Sun, the yield per square foot of installed glazing actually goes down. So, the first increment that you do is the most cost effective increment.

There are a number of approaches. The window is one. A small convective air heater, just hung on the south side of the house, is another. The attached greenhouse is a third.

Many of our buildings have masonry walls already, and this is an embodied value and embodied energy in the building. Rather than to tear them down as we frequently do, why don't we use that valuable mass in place, glaze it on the outside and make a Trombe wall out of it. A few people are doing this.

Mr. GREENE. I have no further questions at this time, Mr. Chairman.

Mr. Moss. The Chair recognizes the gentleman from Tennessee, Mr. Gore.

Mr. GORE. Thank you, Mr. Chairman.

Thank you, Dr. Balcomb, for your testimony. I have enjoyed listening to it. I have followed some of your work in this area. I have had occasion to communicate with you earlier this year during the markup of the solar portion of the energy bill and I appreciated your assistance.

I am interested in your comments on the tax incentives. It appears in summary that we give tax incentives to the least cost effective form of solar energy and we deny tax incentives to the most cost effective form of solar energy.

I can readily imagine the administrative difficulties in applying tax incentives to all passive solar designs. One can hear the criticisms of tax credits for swimming pools, for example, when they are incorporated into passive solar design.

Yet, there must be some way to circumvent those problems and apply tax incentives to the most cost effective form of solar energy.

There is another way that the Government can help in the effort to promote greater use of solar energy, and that is through research and development.

I want to ask you whether in your opinion research on passive systems has been adequately funded, and is it now being adequately funded?

Dr. BALCOMB. In hindsight we can see that we could have put more of our funding into passive solar, but it was not generally appreciated a few years ago how effective these techniques would be.

As we have been able to accumulate evidence to the effectiveness of it, the budget has been creeping up. I am appreciative of the fact that our work at Los Alamos has been supported and we have been able to get the results that we have obtained.

We now have an additional 31 R. & D. projects on passive solar funded out of the Department of Energy throughout the United States. So, the signs are positive and I hear indications that there are tentative plans for significant further increases.

To say that we know how to do these particular things now is not to say that further research is not needed. We need to understand the energy flow in buildings much better.

We need to understand how buildings, other than just the Trombe wall approach which we have gone a long way with, work, and extend our evaluations to a variety of hybrid designs incorporating different technologies, such as active solar with passive, or passive solar with heat pumps.

We have already scratched the surface on these things, but there is a great deal to be done.

We need to learn more about how the microclimate—that is, the climatic variations on a particular site—affect the building, the effect of how the land lies and the trees around the building, the vegetation around the building. These all have some effect on the environment that the building sees. There is a lot of work to be done.

Mr. GORE. My impression is that a very small fraction of the Federal effort in solar energy is devoted to passive solar energy.

Indeed, knowledgeable people within DOE I think now concede that we have made a mistake in not devoting a larger share of our resources to development of passive solar energy and popularization of passive solar technologies.

Would you agree with that?

Dr. BALCOMB. Yes; I think so.

Mr. GORE. You mentioned a couple of areas where further research and development is needed. Could you elaborate and rank in order of priority the most important passive solar research projects that you think our Government should undertake?

Dr. BALCOMB. I would distinguish between systems development work, things like R. & D., and activities which are directed toward implementation of this technology, or commercialization effort.

I will just talk to the former; that is, the R. & D. type of activities.

We need an expanded effort in mathematical simulation and systems analysis directed toward understanding the components,

understanding the solar gains and their effect on the building, and the mechanisms of radiative cooling of buildings.

We need a more thorough understanding of building energy loss mechanisms, which has to be strongly coupled with research on energy conservation going on within the country, and how heat flows around within the building.

These passive solar buildings are generally strongly heated from one side. We need to see how that heat can be transferred passively to the north side of the building without creating unlivable environments.

I mentioned the site climate analysis previously.

We need to expand on validation procedures of our mathematical approaches, and to carry forward systems analyses to study the whole variety of designs and climates that we have to work within, in order to select those technologies and approaches which are most effective in various climates.

We need to develop user-oriented design techniques so that architects, engineers and builders have tools, design tools ranging all the way from rules of thumb up to perhaps desk top programable calculator techniques for predicting the performance of their building with certainty before they build it.

We also need to find out how buildings really work by measuring them, assessing their performance by putting in instrumentation. This is a difficult and costly thing.

We could get a little bit of data from a lot of houses that would be very useful. We could also get detailed data from a few houses, and that would be useful. I would favor such a combined approach.

We need to understand thermal comfort better and the effect of the radiant environment in a room on one's perception of comfort and develop performance measures, and testing and data interpretation techniques so we do things on a common basis.

We need to develop materials, such as improved glazings—of particular importance—and also improved thermal storage materials, and put these into assemblies, such as glazing assemblies, and movable insulation assemblies, and support the development of such products.

We need to develop controllers, actuators and sensors.

These are the principal areas of research I would identify.

Mr. GORE. A very comprehensive list. That should keep a lot of people busy for a while. I know, after looking at the Department of Energy's budget, that we really are not paying enough attention to the contribution that passive solar systems can make.

Now, I want to move from the R. & D. area to the commercialization area.

What institutional barriers do you believe are most significant to the spread of passive solar technology?

Dr. BALCOMB. I could identify about nine barriers to rapid commercialization. I will list those, if you like.

Mr. GORE. Please do.

Dr. BALCOMB. Perhaps the most important is the resistance to any change in a very traditional building industry. They have a product now, they are able to sell it, and they don't want to take risks on something different.

Mr. GORE. Well, you know, I find that that is changing pretty rapidly, if I may interject.

I held a 2-day workshop in my congressional district this past January and invited builders, contractors, builder supply people from the 25 counties that I represent in middle Tennessee.

The response was overwhelming, really. We had 750 people come for 2 full days. I think the building industry is ready to move with these technologies if they can find out where to get them, where they are readily available, if they have some means of easily demonstrating to their customers that they are going to save money in the long run.

I begin to see some small market penetration today. Of course, I would agree with you in general that is an institutional barrier, but I believe we have put too much emphasis on that barrier.

I think if we get rid of some of the others, that one will disappear. Excuse me for interrupting. Go ahead.

Dr. BALCOMB. My second point is related to that, in fact. It is a lack of knowledge and understanding among both buyers and builders of the viability and potential benefits of passive solar. People don't ask for it because it isn't available, and builders don't make it available because people don't ask for it.

We need an education program. Of course, the increase in building first costs is common to all solar energy. That represents a barrier, without doubt. There is a lack of widely demonstrated marketable designs for a variety of building types.

Mr. GORE. Let me interrupt you there. You say there is an increase in first cost. I believe that is the case with most active solar systems. I was not aware that that is also a characteristic of passive technologies.

Dr. BALCOMB. In my testimony I indicated range of costs for the various passive technologies. Those are increases in the building cost over and above what they would be without passive solar.

With the exception of simply adding south windows in lieu of windows other places, there will be some increase in cost. There have been some cases where those increases have been very small.

But as we try to incorporate these concepts really effectively, we need to add insulation, add mass, add glazing, and this is bound to increase the cost, in much the same way that added insulation in the house increases the cost.

Mr. GORE. I have advocated a look at new mortgage instruments to take that into account possibly, but go ahead. What is the barrier that you listed after that?

Dr. BALCOMB. Lack of widely demonstrated marketable designs for a variety of building types. There are just very few examples around yet.

Mr. GORE. The Department of Energy does have a booklet on solar building design, but it is very inadequate, in my opinion. I would certainly agree that that is a major barrier.

Dr. BALCOMB. Inadequate in the passive solar area certainly.

Mr. GORE. Correct.

Dr. BALCOMB. There is a lack of disseminated design techniques suitable for use by the architectural and builder community.

I would list building codes and unenlightened building code enforcement also as a barrier.

Mr. GORE. In what areas do the building codes interface in a bad way with passive solar design?

Dr. BALCOMB. The first building codes which were adopted in the country for energy conservation in fact would have precluded most of the designs I showed you because they limit the amount of glass one can use, and with no distinction as to where it is.

There has been some correction of that in certain instances, but many of the things that we are talking about do have building code problems using the traditional building codes.

Furthermore, the enforcement of those codes is sometimes done by people who do not have a good appreciation of passive solar concepts and are reluctant to deviate or stretch the code in any direction.

There is a lack of zoning and statutes to protect the solar rights of the property owners, so that a person may put in an investment in a solar house and subsequently be shaded by neighboring buildings or trees, and lose much of the gains that he sought to achieve from his investment.

There is a lack of incentives to save energy in general. I have indicated a potential barrier is a tax credit which aids active system designs, but not passive ones.

Mr. GORE. Is that No. 8?

Dr. BALCOMB. Yes.

Mr. GORE. I think those are all the questions I have, Mr. Chairman.

Thank you very much, Dr. Balcomb.

Mr. MOSS. Mr. Wunder, do you have any questions?

Mr. WUNDER. Yes. Thank you, Mr. Chairman.

Dr. Balcomb, in looking at your slides, I was wondering what the situation is in the summertime. Your presentation was almost entirely related to heat, and the wintertime, with all those windows—what happens in the summertime?

Dr. BALCOMB. I indicated, when I started, that the changing sun angles with times of year is in your favor, if you design to account for it. The sun can be excluded by overhangs on these windows.

Mr. WUNDER. Totally?

Dr. BALCOMB. In the summer, yes.

The other things people do is put up a movable slide so that twice a year they change the geometry slightly by putting up a shading device which keeps the sun off of the solar wall.

It is an advantage in a building to have additional mass in it in the summer because in every climate there is a substantial day-to-night swing in temperature, even in this climate here in the summer.

A massive building averages that out, so you don't feel the afternoon extreme. In other, more arid climates, these day-to-night swings are very large and throughout the Southwest it is possible to use this mass effect in the building to great advantage.

They are finding in California, particularly in the Sacramento area, these passive solar buildings use much less cooling energy in the summer as well because of the added mass in the structure and feel that that is equal in importance.

Mr. WUNDER. These buildings you are talking about, are they office buildings or are you talking about houses?

Dr. BALCOMB. Both. Primarily houses because that is primarily what has been done, but it applies to both. We have to keep the sun out of the building in the summer. That can be done by design.

An added 80 square feet of glass on the west wall adds a ton of air-conditioning load. So, you don't put your glass on the west wall, or if you do, you shade it.

Mr. WUNDER. With respect to your house, how much more did it cost if you were to build it conventionally? What was the additional cost?

Dr. BALCOMB. The builder estimated the cost of the greenhouse and an active element, which I didn't go into, reinforced rock bed, which takes air from the greenhouse and holds it in the house, at \$8,000 additional cost in a house that costs a total of \$80,000.

But the appraisal indicates that the value of the greenhouse is at least \$4,000 itself, so I would say the solar add-on cost is of the order of \$4,000.

Mr. WUNDER. You mentioned zoning as being something that was hindering development. I was just playing around as you were talking, with my own hand-drawn subdivision plat here. Are there any land use consequences due to the fact that the panels should face south?

Would that require, say, in a subdivision less houses being built on the same amount of land?

Dr. BALCOMB. Not necessarily. One can lay out subdivisions and cut the lots up in such that you account for this. In fact, there is quite a bit of experience in this in South Africa.

I was visited by the principal of an architectural firm there who was astounded by our practices in this country. They have used passive solar techniques for many years there and consciously lay out their subdivisions so that one can get good exposure to the north. Of course, that is south of the equator.

Mr. WUNDER. Just the opposite, yes.

Dr. BALCOMB. Just the opposite. There have been a number of studies which have indicated that the subdivisions can be laid out—without any changes at all we can still accommodate lot orientations to some extent—and designs have been proposed which will fit on just practically any lot. But they don't work as well, of course, as if you start from scratch to do the job right.

Mr. WUNDER. With respect to lot orientation, given the fact, wouldn't there be a definite uniformity to the housing pattern, given the fact that they all had to face in the same direction?

Dr. BALCOMB. You saw in my examples houses that were long east-west and houses that were long north-south, using clerestory windows. There would be a lot of glass facing south throughout, but that is the only thing I can think of.

One can mix up architectural styles. You saw quite a variety of styles in my slides.

Mr. WUNDER. I am not talking about architectural styles now. I am talking about the way the streets would look. I am talking about esthetics now, as opposed to—esthetics of the community or neighborhood, so to speak, as opposed to the esthetics of a given house.

Would there be a certain uniform esthetic appearance as a result of the fact that they all had to face in that direction?

Dr. BALCOMB. I don't think that is a necessary conclusion. There would be a tendency to make the blocks a bit more shallow in the north-south direction, so that the frontage could be increased to give the house more exposure on the south side.

Houses which are on the north side of the street would have small windows seen from the street. Houses on the south side would have larger windows seen from the street. So there would be that general prevailing tendency. But I don't regard that as an adverse effect.

Mr. WUNDER. Thank you, Mr. Chairman.

Mr. Moss. Dr. Balcomb, I want to apologize for having to be absent twice during the questioning.

I found your presentation interesting and helpful. We are grateful to you for coming here and giving us the benefit of your statement. If there are no further questions at this time, we will excuse you.

The next witnesses will be Scott A. Noll, University of New Mexico; Mr. Jeffrey G. Witwer, SRI International, and Alan Hirshberg, principal, Booz, Allen & Hamilton.

Gentlemen, we have a rollcall now underway in the House. The committee will break for 10 minutes to respond to the rollcall and then we will resume.

[Brief recess.]

Mr. Moss. The committee will be in order.

Gentlemen, I understand you each have a statement. We will start with Mr. Noll, of the University of New Mexico.

STATEMENTS OF SCOTT A. NOLL, RESEARCH ASSISTANT PROFESSOR IN ECONOMICS, UNIVERSITY OF NEW MEXICO; JEFFERY G. WITWER, SRI INTERNATIONAL; AND ALAN S. HIRSHBERG, PRINCIPAL, BOOZ, ALLEN & HAMILTON, INC., ACCOMPANIED BY J. DOUGLAS BALCOMB, PH. D., LOS ALAMOS SCIENTIFIC LABORATORY

Mr. NOLL. Mr. Chairman, I am very pleased to be here today. I have prepared written testimony that I would like to read to you all.

The ultimate desirability of most energy technologies is determined by three factors: reliability, cost, and performance. The importance of these elements applies equally to both energy supply and energy conserving technologies.

A fuel conversion and delivery system may look favorable in terms of Btu's produced relative to first cost, but in many instances the problems of downtime and heavy maintenance are not given proper recognition.

To correct for these deficiencies, additional investments must be made for improved controls, higher quality materials and components, respecification of designs, and so forth. The cost of such quality improvements to insure reliability is oftentimes substantial, thereby diminishing the technology's competitive advantage in the marketplace.

Passively sun-tempered dwellings are unique because the heat is transferred from one point to another by natural means. With the proper integration of thermal mass, the sun's energy can be stored

for delayed delivery, which improves the Btu yield and dampens what may be uncomfortable temperature swings.

With no circulating pumps, no elaborate duct work and controls and no pipe joints to maintain, passive solar heating concepts require little, if any, maintenance. In certain instances, however, small air blowers or fans should be installed to facilitate movement of heat between various zones in the building.

One passive solar maintenance consideration is that of glazing, which depends on initial material quality and installation. The need for glazing replacement can vary from annual replacement of an inexpensive, low quality material such as polyurethane film to occasional breakage replacement for a more permanent material such as glass.

While passive solar designs allow for heat gain during the day, they warrant some form of movable insulation to prevent heat loss at night. This becomes important especially in the more severe northern climates where nighttime temperatures can fall to extremely low temperatures.

Many night insulation devices are in the development stage, with several brands available in production quantities. Costs fall in the range of \$1 to \$7 per square foot and vary with respect to degree of automation, insulating materials and edge sealing systems.

Because night insulation device maintenance costs are of prime consideration, continued improvements in automation and specific design can be expected in the future. These improvements will make the night insulation device an even more cost effective addition to passively heated structures.

Although further development of specific components is necessary, passive designs are usually constructed with the use of time-tested building materials, which when combined with a simple heat delivery system insures reliable operation over an extended period of time.

Turning now to add-on first costs, three elements in particular make passive solar a desirable investment. These are: One, the use of conventional building materials and labor skills for which the supply networks already exist;

Two, the fact that passive concepts can be integrally designed into a building shell and thereby take advantage of economies in construction; and

Three, the important consideration that one can design for as little or as much passive heat gain as desired within the constraints imposed by southern exposure areas, local building codes, and climate.

At very low cost additional window area can be designed into the south side of a new home with simultaneous reductions in northern window exposures. At additional expense, the southern exposure can be expanded and thermal mass in the form of concrete or water storage can replace interior walls and floors for better performance.

Further improvements can be obtained by adding a night insulation system that admittedly increases first costs, but in most every instance pays for itself in terms of energy savings within 2 to 10 years.

Although some passive concepts cannot be characterized by the above-mentioned initial cost advantages, most passive designs do benefit from these factors and can be installed at a relatively low incremental cost.

Passive retrofit design offers a tremendous opportunity to supply a portion of heating requirements in the existing building stock. Attached sun spaces, clerestory and sawtooth window arrangements, and utilization of existing structural mass are ideas that have been successfully retrofitted to a wide variety of building types, both residential and light commercial.

Furthermore, in some cases substantial economic benefits have been realized by the use of natural daylighting techniques to offset power requirements for conventional fluorescent and/or incandescent lighting.

Actual experience and further cost estimation by passive solar architects and builders shows that incremental capital costs vary significantly according to the generic design, system sizing, and the degree of finishing.

The following figures show the range of representative incremental unit costs in dollar per square foot of collector for the five generic system types:

Thermal storage wall, \$8 to \$18; direct gain, \$2 to \$13; attached sun-space, \$5 to \$15; thermal storage roof, \$10 to \$25; convective loop, \$5 to \$8.

These are solar add-on costs computed as the difference between the cost of the building with the passive system less the cost for conventional construction.

Experience to date has indicated that typically sized passive solar additions have total installed system costs in the range from \$2,000 to \$8,000, depending, of course, on the type of passive system, the climate, the particular building and the solar fraction supplied.

The important question then becomes, will such expenditures be cost effective; that is, will the Btu cost of delivered heat to the home from a passive addition be cheaper than the Btu cost of delivered heat from a conventional energy source such as electric resistance, heating oil, or natural gas?

Many indicators of economic competitiveness have been used to rank the relative merits of various residential solar systems. A partial list would include simple payback, number of years until a net positive cash flow is generated, net present value of systems benefits, equivalent annual dollar per million Btu costs, and so forth.

By looking at a combination of these financial and economic indicators one can get a feeling for the relative competitiveness of an investment in passive solar.

It is equally true, however, that many assumptions concerning mortgage and discount rates, inflation and fuel escalation rates over time, system life, terms of the loan, et cetera, must be specified to properly evaluate economic performance.

The results presented in the following summary tables are taken from a particular set of runs based upon the Los Alamos Scientific Laboratory—LASL—solar load ratio performance methodology and

the University of Mexico/LASL State-by-State economic comparison methodology.

Thermal performance is based upon a double glazed Trombe wall integrally designed into a 1,500 square foot single family residence with a system of movable nighttime insulation.

A nationally indexed cost of \$12 per square foot of collector area is adjusted for each particular location to account for variability in material and labor costs. Seven representative locations serve as the basis for comparison, and systems are sized so as to maximize the net present value of benefits in terms of energy savings over a 30-year time horizon.

What this basically shows is the performance of a Trombe wall on a life cycle costing basis; that is, we look at the stream of cost, in terms of initial cost, operation, and maintenance and backup fuel over the lifetime of the system, and we compare that to the lifetime costs that would occur if the passive solar system had not been installed.

When one does this, you can compare it against any particular alternative. I have three different slides here. They are electric resistance, heating oil, and natural gas.

The basic conclusion to be drawn is that if electric resistance is your alternative, yes indeed it does pay on a life cycle basis to install the passive system.

Some indicators of financial performance show—one is simple payback, and this shows the initial cost of the passive system against an electric resistance alternative across these seven locations can be recovered in 8 to 10 years.

Another indicator is the number of years it takes for a positive cash flow to be generated; that is, how many years does it take before the annual savings exceed the annual costs.

Against the electric resistance alternative, with systems providing anywhere between 45 and 60 percent of the heating load in the building, a positive cash flow is generated in the first year.

In addition, one would like to look at the net present value of savings—that is, the present value of costs without the system—minus the present value of the costs with passive solar. These are on the order of \$2,000 to \$5,000.

So, indeed it looks like a very attractive investment.

We go to heating oil. Heating oil is a cheaper alternative than electric resistance. Therefore, in terms of optimal sizing—that is, that size system that will maximize the value to me over the system life—it does not pay me to size it quite as large.

At some point it becomes cheaper for me to buy additional heating oil than it does to put in additional passive solar, but nonetheless, it does compete against this alternative.

Let's go to natural gas. The price of natural gas is low enough in most locations to make it only marginally feasible or economically competitive to put in passive solar when this is your alternative.

On a life cycle costing basis, it only pays to put in systems that are very small; that is, only to do a very little amount of passive solar. This can be indicated by the areas.

This is just indicative that it does not pay to put in a large system when natural gas is your alternative. I doubt if anyone would put in a 31-square-foot Trombe wall.

This does indicate that one could use perhaps the concept of an additional window on the south area of the building, and it would pay against natural gas, but only a very small amount because natural gas is cheap.

May we have the lights again, please. Thank you.

To summarize, the table shows that passive solar competes quite favorably against the electric resistance alternative. Simple payback periods are relatively short—8 to 12 years—annual savings exceed annual costs in the first year of operation, and net present values are substantial. On a life cycle costing basis, it would be economically competitive to install passive systems in most locations today if electric resistance were the only available heating alternative. This even holds true for more expensive systems which cost on the order of \$18 to \$20 per square foot of collector, although payback periods and years to positive savings will be lengthened with corresponding decreases in net present values.

If one has the alternative of purchasing natural gas, which is much cheaper on an equivalent dollar-per-million Btu basis than electricity, passive solar systems still compete, but only at very small system sizes and solar fractions. As system size increases, the cost of each additional passive Btu provided becomes more expensive, so at some point one would spend less money by purchasing natural gas rather than providing more passive solar energy.

Other studies have shown that direct gain systems with storage mass exhibit similar or better economic and thermal performance characteristics as the Trombe wall described above. Even more promising are attached sunspaces and convective loops which can be installed (new and retrofit) for under \$10 per square foot of collector area. Studies by Booz, Allen & Hamilton and further compilation by the Solar Energy Research Institute of additional passive solar studies has verified that such concepts are indeed cost effective.

I have not talked about many other aspects of passive solar applications such as cooling, natural daylighting, water heating, livestock shelter heating, and agricultural crop drying uses. However, it is important to point out that those applications offer the potential for widespread utilization of passive solar design and architecture now and in the near future. More research needs to be undertaken in the passive solar field, yet we are in a situation where some passive heating techniques are ready to be commercialized in residential, multifamily, and light commercial applications. I would encourage the U.S. Congress to support such a program, because the return in terms of energy savings could be significant, and no substantial harm to the environment would result.

Thank you very much for the opportunity of sharing these thoughts with you.

[Tables attached to Mr. Knoll's statement follow:]

ECONOMIC PERFORMANCE OF PASSIVE SOLAR RESIDENTIAL HEATING TROMBE WALL

ELECTRIC RESISTANCE FUEL ALTERNATIVE

YEAR	SOLAR FRACTION	AREA	TOTAL COST	YIELD MMBTU/YR	\$ MMBTU/YR	DELIVERED HEAT COST \$/MMBTU	CONVENTIONAL COST \$/MMBTU	SIMPLE PAYBACK TIME	YEARS TO POSITIVE SAVINGS	\$ NET PRESENT VALUE
LOS ANGELES, CA	.65	134	1747	18.1	96	8.18	11.83	8	0	2098
ATLANTA, GA	.55	241	2508	22.0	114	9.54	12.22	9	0	2302
BOSTON, MA	.50	397	4841	38.0	127	11.47	14.74	8	0	5212
ALBUQUERQUE, NM	.65	314	3466	38.2	91	7.73	11.21	8	0	4222
CLEVELAND, OH	.35	307	3970	30.0	132	11.46	13.04	10	0	3021
MEDFORD, OR	.30	145	1815	19.1	95	7.28	7.79	12	0	831
MADISON, WI	.45	422	4617	47.8	97	8.99	11.26	8	0	5032

ECONOMIC PERFORMANCE OF PASSIVE SOLAR RESIDENTIAL HEATING TROMBE WALL

HEATING OIL FUEL ALTERNATIVE

YEAR	SOLAR FRACTION	AREA	TOTAL COST	YIELD MMBTU/YR	\$ MMBTU/YR	DELIVERED HEAT COST \$/MMBTU	CONVENTIONAL COST \$/MMBTU	SIMPLE PAYBACK TIME	YEARS TO POSITIVE SAVINGS	\$ NET PRESENT VALUE
1978	.60	116	1521	16.7	91	7.32	9.49	12	0	1313
1978	.45	182	1898	18.0	105	8.17	9.30	14	0	1079
1978	.40	287	3502	30.4	115	8.75	9.61	14	2	1694
1978	.55	237	2615	32.3	81	7.03	9.26	11	0	2745
1978	.20	152	1963	34.3	77	8.68	9.01	15	4	776
1978	.40	214	2680	25.5	105	8.40	9.49	14	0	1634
1978	.45	422	4617	47.8	97	7.75	9.01	13	0	3055

ECONOMIC PERFORMANCE OF PASSIVE SOLAR RESIDENTIAL HEATING TROMBE WALL

NATURAL GAS FUEL ALTERNATIVE

	YEAR	SOLAR FRACTION	AREA	TOTAL COST	YIELD MMBTU/YR	\$ MMBTU/YR	DELIVERED HEAT COST \$/MMBTU	CONVENTIONAL COST \$/MMBTU	SIMPLE PAYBACK TIME	YEARS TO POSITIVE SAVINGS	\$ NET PRESENT VALUE
LOS ANGELES, CA	1978	.10	14	180	2.8	64	4.21	4.22	19	12	27
ATLANTA, GA	1982	.10	31	326	4.0	82	5.41	5.42	18	12	56
BOSTON, MA	1978	.30	201	2457	22.8	108	7.70	8.03	17	9	783
ALBUQUERQUE, NM	1978	.10	34	371	5.9	63	4.10	4.11	19	12	53
CLEVELAND, OH	1984	.10	68	873	8.6	102	6.81	6.83	18	11	158
MEDFORD, OR	1978	.25	115	1443	15.9	91	6.80	7.12	17	8	571
MADISON, WI	1978	.20	147	1606	21.2	76	5.67	5.87	17	9	601

Mr. Moss. Thank you.
Mr. Witwer.

STATEMENT OF JEFFREY G. WITWER

Mr. WITWER. Mr. Chairman, I am glad to have this opportunity to testify before you this morning on the timely topic of passive solar energy.

Early in 1977 ERDA's general advisory committee, which is a nongovernmental group of people advising the Atomic Energy Commission and then ERDA on their energy research program, undertook a critical review of ERDA's solar energy program, to try to determine the balance between the various solar alternatives. The general advisory committee became the Solar Working Group when ERDA was reorganized into DOE, and they contracted with Stanford Research Institute to provide technical support in this review.

The SRI work, for which I was the leader, was completed in January 1978. The Solar Working Group issued their report based upon this analysis a few weeks later. My testimony today is based upon the findings of this project as well as my continuing investigations of solar R.D. & D. and policy issues made over the past 7 months as an ASME congressional fellow serving on the staff of the Energy and Power Subcommittee of the Interstate and Foreign Commerce Committee.

The analysis of R.D. & D. priorities, which was done for the Solar Working Group, was a complex multifaceted process which included many field interviews, computer simulations of market penetration, and a lot of investigations and briefings into the DOE program itself. It involved experts from a wide variety of fields. Its scope included all the major solar options: heating and cooling of buildings, wind, biomass, photovoltaics, ocean thermal energy conversion, process heat, agriculture, industrial process heat, and thermal power. I will just summarize here the important findings, especially as they relate to passive solar applications.

We developed a process which would incorporate many criteria which would permit R.D. & D. alternatives to be prioritized based on a wide variety of criteria. For example, one of the criteria was market potential which sought to identify the solar technologies that would contribute the most to national energy supply under several energy price and demand scenarios.

The environment criteria sought to identify the solar technologies that would have the highest environmental benefits themselves and which would replace the most environmentally adverse alternatives.

Insurance criteria sought to identify solar technologies which could be relied on to provide energy to the Nation under conditions of extremely high alternative prices that could result, for example, from limits on the availability of conventional energy supplies or severe environmental constraints on conventional energy supplies.

The speculative criteria sought to identify the solar technologies that would have the possibility of supplying major fractions of our national energy needs because of their simultaneously meeting a

major energy demand and at the same time utilizing a large solar resource base.

The conservation criteria sought to identify solar technologies which directly conserve oil and gas which were seen as being the conventional fuels with the smallest national resource base. The central/decentral criteria sought to identify solar technologies which were decentralized in use so that the potential applications of small-scale applications could be realized.

Finally, the international criteria sought to identify solar technologies which might lead to significant export markets either of the hardware or of services.

Each of the solar options was analyzed in terms of the seven evaluation criteria. From this technical analysis the solar technologies were ranked, relative to each other, according to their scores based on the evaluation criteria. The resulting rankings, which are shown in table 1, suggest that solar heating of buildings dominates in terms of high net benefits in all time periods.

The important results of this were, in terms of the topic of this hearing, that solar heating of buildings is a technology which results in high benefits as measured on the basis of these criteria.

[The table referred to follows:]

TABLE 1.—SOLAR TECHNOLOGIES RANKED BY TOTAL BENEFITS

1985	2000	2020
SHACOB ¹	SHACOB	Wind
Biomass	Wind	SHACOB
Wind	Biomass	Photovoltaics
Photovoltaics	Photovoltaics	Biomass
Thermal power	OTEC	OTEC
Process heat	Thermal power	Thermal power
OTEC ²	Process heat	Process heat

¹ Solar heating and cooling of buildings.

² Ocean thermal energy conversion.

Mr. WITWER. This ranking is rather qualitative. It is not really as quantitative as it might suggest. The whole system was numerically based, and was computerized so that many sensitivity runs could be made. For example we looked at the importance of weighting the different criteria and alternative costs. By looking at these rankings as a tool, we gained insight into the R. & D. needs of each of the technologies.

I will just make a few comments about the findings as they relate to solar heating and cooling of buildings. The classification of solar heating and cooling of buildings which yielded these high results was in fact a grouping of all the major ways of directly using solar energy in buildings, that is, solar water heating, active solar heating and cooling and passive solar heating and cooling. A more detailed analysis of the results showed to us that the reasons solar heating and cooling looked like such a good technology in terms of the benefits was because of two specific technologies that were included in this grouping. Those technologies were solar water heating and very inexpensive space heating systems. These inexpensive space heating systems were of the passive type, and also active heating systems which were low in cost because there

was a large element of "do it yourself" labor that was not counted in the cost.

These two technologies, water heating and inexpensive passive and active space heating, received the high benefits because primarily they were very attractive in terms of the market potential. They also received high rankings in some of the other criteria such as environmental and insurance characteristics.

The analysis, along with an examination of the current Federal R.D. & D. program, formed a basis for conclusions about the relative balance within the Federal solar program. In the area of passive solar heating there was general agreement that Federal attention to date had been inadequate, particularly in light of the apparent high benefits resulting from this technology. It was concluded that the areas in which expanded Federal efforts would be warranted were, (a) the development of more adequate quantitative models to analyze passive alternatives. I would add that that was one of the points that Dr. Balcomb mentioned in his testimony; (b) Expanded information dissemination to various user classes—and again Dr. Balcomb alluded to this in his list of incentives which must include homeowners, architects, contractors, building equipment manufacturers, and so forth, in order to get acceptance in the marketplace; (c) more widespread demonstration of passive buildings in the Federal home heating and demonstration program, emphasizing a wide range of design approaches and geographical locations.

The past neglect of passive solar heating can at least in part be attributed to some inherent characteristics of the technology. For example because all buildings are, in fact, already passively solar heated with normal incident sunlight, passive technology generally involves simply doing more of what is already done. Again, this was brought out in earlier testimony.

Although many discrete passive design principles can be identified, the distinction between a passively heated building and a "conventional" one can seem to be somewhat arbitrary. For example, how many windows do you put on the south side before it is a passively heated home, and with how many windows is it still a conventional home? The difficulty in drawing these distinctions has, for example, led to some difficulty in designing financial incentive programs which include passive designs. It also has led to organizational confusion in the Government's own program. For example, passive solar heating was initially included in the conservation program as opposed to the solar energy program.

One of the things that I have noticed is that when a technology is put in two different agencies or two different groups that have jurisdiction over a technology, two things can happen, and unfortunately they both tend to be bad. One of the things is that both groups can both pursue the technology very vigorously in which case there can be a lot of waste and duplication. In fact competing groups can become more involved in beating the other organization than into getting the technology improved.

The other thing that can happen is that the technology can fall through the cracks and be ignored because both groups think the other group is doing it. I think in the case of passive heating unfortunately the latter happened in that neither the conservation

program nor the solar program took an active enough approach to passive solar heating.

A related factor which can lead to the neglect of passive solar heating is the tendency to measure the effectiveness of Federal energy R.D. & D. programs in terms of readily identifiable units of energy produced such as barrels of oil, kilowatt hours of power, and so forth.

Technologies such as passive solar heating, which simply tend to reduce the consumption of other energy sources, as opposed to actually producing a marketed energy product, tend to be neglected as orphans. Unfortunately, in the maze of Federal R.D. & D. program planning activities, it is probably still better to produce a barrel of energy than to save one.

Even active solar heating is at an advantage compared to passive technologies. For example, the use of active solar heating can be monitored relatively easily by measuring the total area of solar collectors which are manufactured within some period. A comparable simplistic number to measure progress in passive solar uses is not available.

These special characteristics of passive solar heating suggest that, in addition to the technology-oriented recommendations made earlier, there are policy changes that could be made to facilitate the wise use of passive solar heating. These would include:

Better coordination between Federal conservation and solar heating programs. It seems that this need was at last formally recognized in the reorganization of ERDA into DOE in which conservation and solar heating programs were grouped under the Assistant Secretary for Conservation and Solar Applications. How effective that reorganization will be remains to be seen.

The second proposal would be to eliminate subsidies and other policies which artificially hold down the price of conventional energy supplies.

Third, I would mention that we need to resist the temptation to overspecify standards for building construction. Now this is one of the points that Dr. Balcomb suggested, and I want to emphasize the importance of it. Dr. Balcomb gave the example of how standards originally limited the area of glass that you could have. It was felt that was a good way to reduce energy consumption. What it did in fact was cut down on the amount of passive solar gain. Standards should be performance based, that is by regulating the annual energy consumption per square foot of living area, as opposed to design based, that is requiring certain types of hardware.

In the same way that standards can be difficult, so can be incentives. Mr. Gore mentioned this during his earlier questioning. An example of this will be illustrative. One of the ways we can go about passively heating a home would be to spend \$1,000 on a lot of hardware—windows, thermal mass, and things like that. That might have the effect of raising the temperature of the building by 10 degrees or so.

Another alternative would be for a person, instead of spending \$1,000 for the passive heating system, to wear a sweater. This probably is the cheapest passive heating system that you could imagine, and that might cost \$20.

Now the difficulty that we could get into with overregulating and overspecifying and overidentifying standards is that we might discriminate against the person that is willing to wear the \$20 sweater in favor of the person that is willing to pay the \$1,000 for a solar heating system, even though they both might in fact save the same amount of energy.

Over the past year it seems that more people have become aware of the potential of passive solar heating. This shift needs to be encouraged. Although passive heating techniques are not a panacea which will solve all of our energy problems, the simple fact is that for some building types, the judicious use of passive principles makes good sense. Although there are areas of passive heating which require more technical development, there is much known in this area right now, which through aggressive commercialization efforts, such as those mentioned earlier in my testimony and in that of Dr. Balcolm, can improve the buildings we are building today. Because buildings can remain in use for over 50 years, each new building which does not incorporate these known principles will long stand as a monument to a failure of Federal leadership.

That concludes my prepared testimony and I will be glad to respond to any questions you may have.

Mr. Moss. Mr. Hirshberg, we will be very happy to hear from you. Let me explain that we have a minifilibuster going on on the floor, and so we will be plagued with bells and it will necessitate some disruption of the hearings as we go along. I apologize for that.

STATEMENT OF ALAN S. HIRSHBERG

Mr. HIRSHBERG. There are at least three components which need to be considered and coordinated when we discuss solar passive policies. First, research and development and other technical considerations. Second, the questions of cost and economic studies in general, and third, commercialization policies and programs. The first two of these items have been discussed by previous speakers. I will concentrate primarily on the commercial questions. First, I do want to discuss the policy background as I see it, and give a brief overview of our estimate of the status of passive solar energy systems.

Federal policy sets the rules of the game in which the marketplace economic decisions are made. There are rules and policies of the Federal Government now that do in fact restrict the development and use of cost effective solar energy systems and conservation. The lack of replacement cost pricing of fossil fuels and electricity will continue to discourage the effective use of solar energy systems.

Implicit in explicit rules as evidenced by the Federal energy budget also restrict the use of solar energy. In my reading of the Federal budget for solar, there seems to be a stress on large centralized technologies to the exclusion of cost effective use of solar energy and conservation. There is an emphasis on research and development to the exclusion of the encouragement of commercial use of getting these products developed in R. & D. out into the marketplace.

For example, about 1 percent of the current Federal solar energy budget; that is, not the total energy budget but just the solar

portion, is scheduled to be used for developing market strategies, studies or barriers and incentives, technology transfer, and so forth.

It is almost as if we are saying with the budget priorities that the Federal Government will spend billions for research but not one penny to encourage commercial use.

In terms of the status of passive solar, the testimony that was given earlier certainly testifies to the technical availability of passive solar systems. They clearly work. They have been designed in a number of environments in a number of different building types. Preliminary economic studies indicate that the costs of the better systems are comparable to conventional fuel costs, and more careful detailed cost studies are needed, particularly with commercial building industry reference, and I want to stress that. I will come back to that later.

I am afraid, however, that commercial use may be restricted to only small submarkets, unless: (1) We develop systems for use on new tract buildings rather than on the relatively small number of architecturally designed buildings; and (2) we develop systems which can easily be bolted on or retrofitted on existing buildings, and are compatible with building system designs and therefore replicable in a large number of building types.

I think the potential is there for that, as Dr. Balcolm and the others have indicated, but I think there is a difference between the potential and the practical possibility as it exists in today's building industry environment.

Now I would like to move on and talk briefly about what can be done by the Federal Government in terms of these general problems and with more reference to the specific questions of commercialization. First of all, I think correcting the economic signals that we give consumers and businesses is essential. Replacement cost, pricing of fossil fuels and electricity I think is an important first priority. If this is infeasible because of political or practical reasons, then I think we must develop counterbalancing incentives for solar energy.

At this point, we do not understand what all of the incentives are which are necessary and which will work. Therefore, there needs to be more Federal study of incentives specifically for passive solar systems, and which incorporate the understanding, more detailed understanding, of the real factors in the consumer decision process.

We think we know what makes people buy systems. We think we know what makes people interested in passive, but I really do not think we understand that in enough detail.

Second, we need more research and development, and particularly demonstration projects, for passive systems which stress large-scale tract building types of systems, which stress retrofitable systems, such as sun-space systems and others, and a variety of other systems with large market potential.

I think in addition the demonstration project should perhaps be refocused and include what I would call pure cost experiments within them. In other words, they should not be just demonstrations that you can build a system that will work, that will supply 70 percent or 50 percent of a load, but also that will demonstrate

that you can bring down the costs of passive systems over time, and that they can be retrofitted in a specific building context.

Third, I think we need to develop an expanded strategic plan for the commercialization of passive solar systems. I think there is a plan that exists today, although I have not seen it, I think one either exists or is in development, but I think those efforts need to be widely expanded and a lot more effort needs to be put on those kinds of planning and development efforts. We need to build in more private sector involvement in the passive solar energy programs, and we need to perform additional cost studies, particularly in the commercial context.

Now the cost studies and the economic comparisons that I think have been done to date have been done I think competently, but I think they have been done pretty much on a one-of-a-kind type system basis. There have been really no careful studies and documentation of the costs of what I would call the standard building industry environment. We have instead what I would call estimates of those costs in that kind of environment, and we need to move on and develop a strategic plan which incorporates within it a part of a program that actually takes a look at real costs within the building environment, in the building industry itself.

Fourth, I think we need to perform additional market development research. We need to understand the difference between how passive solar energy systems are likely to be diffused within the building industry compared to active systems. I think there is a different chain of people who will be involved, a different chain of distributors, a different chain of users. I am not sure that that is well understood, and I think part of the problem that Dr. Balcomb referred to, with the lack of the information being in the hands of the people who need it, has to do with the fact that what I call the technology delivery system for passive solar is not well understood, and probably not yet really in place.

Furthermore, and as an attendant consequence to this, we need more insight into the barriers to the widespread use of passive solar. Dr. Balcomb again gave a very good summary of those. I won't go back through them. There are additional ones, which maybe we can get into later on. Those need I think to be brought out. I think the barriers need to be examined one at a time, and dealt with one at a time in a programmatic way. In other words, the program needs to be developed that specifically deals with the individual barriers that are identified.

Fifth, I think we need to develop a system for monitoring and tracking the number, the cost, and the performance of passive, and I would say active solar systems, as they get built. One of the things that troubles me is that there is a tax credit that is likely to be voted into law, and maybe some very restrictive standards that may have counterproductive consequences, and yet there is no Federal intelligence gathering mechanism in place, so that we can on an ongoing way understand what is actually happening in the marketplace in response to these incentives, and to continually improve and change and upgrade Federal proposals to take into account what is happening out there.

I think in addition, having this kind of evaluation or monitoring and tracking system will provide useful feedback to the R.D. & D.

parts of DOE that are developing new systems, and I think that piece of intelligence gathering mechanism needs to be put in place.

In summary, I think the time is right for increased activity and emphasis on both passive and active solar systems with particular emphasis upon the development of Federal policies for their rapid commercial use. I hope my remarks have been useful to you, and I will be ready to answer any questions.

[Mr. Hirshberg's prepared statement follows:]

PREPARED TESTIMONY FOR THE HEARING ON THE
TECHNICAL AND ECONOMIC VIABILITY OF
PASSIVE SOLAR TECHNOLOGY*

Given Before The
CONGRESS OF THE UNITED STATES
HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON OVERSIGHT AND INVESTIGATION
OF THE
COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE
August 11, 1978

BACKGROUND

We are here to discuss specific policies relevant to the commercialization of passive solar energy technologies. To understand the context within which commercialization policies will be working, it is necessary to review the roots of our national energy problems.

The energy crisis is not primarily a technical or economic problem, but a crisis produced by institutional and policy failure which has technical and economic ramifications. Current federal policy has established a negative climate for solar energy.

- Public Policy sets the rules of game in which energy purchases are made
- Prices for oil and gas have been kept low by public policy, thereby encouraging high use of fossil fuels. Although these policies helped fuel the postwar expansion, they have outlived their usefulness and are currently counter-productive.
- These policies continue to operate keeping prices for electricity and fossil fuels artificially low, and thereby encouraging their usage to the exclusion of alternative energy sources such as solar energy and conservation.
- In this context, unfavorable economic comparisons of solar energy with other energy sources reflect as much about public policy choices as about the true cost competitiveness of solar.

*Testimony presented by Dr. Alan S. Hirshberg, Principal, Booz, Allen & Hamilton Inc., 4330 East West Highway, Bethesda, Maryland 20014

- If policy could be established free from political concerns, the first phase of a passive solar energy commercialization program should be to allow the prices of the alternative fossil fuels to reflect the true incremental costs of extraction and purchase. By so doing, federal policy would be setting economic signals favoring both the rational use of fossil fuels and the implementation of conservation, and solar technologies.
- We must also look at fundamental institutional failures:

 - Some of the institutions which implemented our energy policy, were and continue to be mainly guided by a conventional wisdom which stresses R&D funding for large centralized technologies. This "wisdom" seems to ignore the fact that over 20 percent of our national energy budget is replaceable by low temperature, decentralized technologies such as solar and conservation.
 - Further more, the conventional wisdom is detrimental to solar efforts. Decentralized technologies and practices such as active solar, passive solar, and conservation continue to face institutional barriers inside the federal government which slow their development.
 - Solar technologies face institutional biases (as those from OMB) which stress R&D nearly to the exclusion of commercialization. For example, about one percent of the 1979 budget (5.7 million of the four hundred million dollars*) was used for commercialization activities. Solutions to problems require implementation otherwise the solution is meaningless. Borrowing from American History, the conventional rules have said, "Billions for Research, but not a penny for commercial usage". This conventional wisdom must be altered if we are to have a successful solar policy over the next ten years.

*U.S. Department of Energy, "Solar Energy: A States Report - June 1978", DOE/ET-0062.

PASSIVE SOLAR ECONOMICS

The intent of our passive solar evaluation was to perform a first cut or preliminary analysis of a broad range of passive solar space heating applications. This we felt would:

- . Help provide input for Federal Solar Energy Policy formation
- . Identify major barriers which could thwart the use of cost effective passive systems, and develop a list of incentives which would help overcome these barriers.*

Key to the viability of passive solar technologies are the economics. Our analysis developed economic indicators by the:

- . Examination of both new and retrofit examples of five passive solar space heating systems:
 - The direct gain or window wall system
 - The hot air thermosiphon or convective loop system
 - The mass wall system
 - The mass roof or roof pond system
 - The sun-space or solar greenhouse system.
- . These systems were applied to four building types
 - Single family home
 - Multifamily home
 - Office
 - School

in eight geographically dispersed cities.

*The Booz, Allen & Hamilton Passive Solar Evaluation is part of the Solar Incentives Impact Model being developed by Booz, Allen & Hamilton Inc., funded by Dr. Roger Bezdek of the Barriers and Incentives Branch, Solar Division, Department of Energy.

Our results to date are only preliminary. Some of the tentative conclusions based on these preliminary results are as follows:

- Passive solar space heating appears attractive in most parts of the country
 - It is competitive with most electric heating systems
 - It is possibly competitive with replacement costs of oil and gas systems.
- It appears that tax incentives for some of the more clearly defined systems will rectify the problem of replacement cost discrepancies.

These conclusions are based on costs that are not too well understood. There has been very little research on Passive Solar cost, and it is strongly suggested that there be more intensive cost studies examining:

- The manufacturing cost trends versus building cost trends
- Investigations of prefabricated systems (bearing in mind the fate of Operation Breakthrough).

Further analysis in our Passive Solar Evaluation has led us to the following conclusions relating to commercialization:

- There needs to be an increased emphasis in commercially oriented passive systems for application on existing buildings (retrofit applications).
- Development of a commercialization study for passive that is:
 - Regional
 - Deals with the people involved in designing, building, purchasing or otherwise involved in the process by which passive solar energy systems are used by people.
- There needs to be better cost studies where the emphasis is on performance (a continuation of the LASL effort) so that we can continue to develop simple yet effective rules of thumb for use in the field.
- Evaluation programs:
 - That will document existing buildings (cost, comfort, performance, and over time)
 - Cost experiments (with related incentives) that encourage cost reductions for builders over some time period.

As stated before, the above are conclusions based on preliminary results of our evaluation of passive solar energy. A more detailed discussion of the problems of commercialization follow.

COMMERCIALIZATION

Passive solar energy commercialization is the process by which we implement this specific alternative energy form. The term "commercialization" has become a popular buzz word, nevertheless, commercialization is a straight forward concept. In our society, the fastest way to gain acceptance of a new good or service is to marshall the commercial incentives in our economy, and to utilize the existing institutional networks which deliver these products to the people.

One element affecting commercialization is federal policy. To this end, it is imperative for the solar effort, that:

- . Federal policy fix the economic signals
 - Include at least some clearly identifiable passive systems in the solar tax incentive package
 - Encourage the swift passage of tax incentives
 - Careful analysis of the replacement economics using marginal (not average) fuel costs
 - Reduction or elimination of property taxes on passive and active solar systems
 - Elimination or equalization of tax write-offs for conventional fuels (since this provides up to a 50 percent subsidy for the use of fossil fuels).
- . An element of commercialization is acceptance of the technology.
 - This phase of the commercialization process is difficult
 - . Passive is not a typical "package" or "bolt-on" technology
 - . Passive solar is a design concept rather than a product. The building industry is set up mainly to favor rapid usage of package products rather than design changes. Further,

the best passive systems vary a great deal from region to region, therefore, development of an easily used passive solar package will be difficult.

- Passive solar energy usually changes the character of a building. Because of economic forces, the building industry is often slow to adopt new technology which threaten building schedules and raise risks.
- Rapid commercial usage must be oriented to the many professionals in the industry:
 - The designer/architect. This person integrates the design concepts into the building.
 - The builder. This person is key to the delivery of the passive solar system for new buildings.
 - He will implement passive if he perceives a market demand
 - He will implement passive if he can create a market demand (as in the selling of fuel efficient homes).
 - The user. Last in the chain of the delivery system is the user. This person must feel that passive solar:
 - Will be effective in reducing annual fuel costs
 - Will create a comfortable environment
 - Will be aesthetically pleasing
 - Will not cause him a financial penalty:
 - As in increased property tax
 - As in increased insurance
 - As in utility surcharges.

THE CHALLENGE

Passive solar technologies are ready for implementation. They work. They are close to being cost competitive with the replacement cost of fossil fuels and electricity. They are sufficiently diversified in physical form that they can be integrated into numerous architectural styles. They work in most climatic zones. The challenge we face is the encouragement of the widespread usage of the passive solar options. We have emphasized two fundamental areas that present a challenge:

- . Federal policy
- . Commercialization.

Though R&D is needed to better the \$/MMBtu ratio, as well as to create an atmosphere within which passive solar heating and cooling innovations can flourish, we stress again the importance of implementation of passive solar technologies.

The challenge of correcting federal policies

- The prices of fossil fuel and electricity which consumers see are still below replacement costs and even with immediate deregulation, consumers will not see replacement costs for many years, because of the Public Utility Commission pricing rules.
- Federal policy should first focus on adopting policies which set right the economic signals:
 - . Either raise energy prices which is politically difficult
 - . Or give tax and other financial incentives to conservation and solar technologies, which are less attractive in terms of economic efficiency.
- Policy should stress certain R&D activities
 - . More intensive work on standardization and rules of thumb (otherwise passive may be limited to the small market of designer built homes)
 - . Development of passive system to be used with tract homes

- Increased research and development activities on hybrid active/passive solar systems for use in mass markets
 - Increased research and development activities on passive solar heating/cooling systems.
- The challenge of Passive Solar Energy Commercialization
 - We need to understand the delivery system:
 - How can the formal and informal communication network be utilized to speed the commercial use of passive solar systems?
 - What design parameters are to be expected in the passive solar purchase decision?
 - What submarkets are most appropriate for passive solar systems?
 - Strategic plans for integrating Federal efforts with the private sector need to be developed for a passive solar program:
 - A study of the real barriers to the usage of passive system needs to be completed
 - A comprehensive commercialization plan linking the most favorable submarkets with Federal R&D and demonstrations needs to be expanded
 - Use of the Regional Solar Energy Centers and Energy Extension Service should be coordinated and focused on commercialization in addition to information dissemination.
 - SERI should not be allowed to become just another federal laboratory, but should develop and maintain a central focus on developing solar policy. SERI should coordinate its role with the regional centers.

- We need research on passive solar systems that are applicable to more than new, architect built homes:
 - . Need to develop retrofitable passive systems such as:
 - Bolt-on thermosiphons
 - Free standing mass storage walls
 - Solar greenhouses
 - Solar chimney's for cooling.
 - . Need to develop passive designs which are applicable to:
 - New tract homes
 - Replicable buildings such as multi-family system buildings.

As a check on commercialization progress, we need to implement programs which monitor and evaluate the progress of the solar industry in order continually improve Federal efforts to speed the commercial use of solar energy:

- . Establish a system to monitor and tract both active and passive installations
- . Establish a system to monitor consumer reactions
- . Avoid restrictive regulations and standards
- . Ease the OMB rules which restrict essential data gathering (that aid in the evaluations)
- . Conduct evaluations of the barriers to and appropriate incentives for passive systems.

It is time to develop and implement incentives and programs that really work—that do more than look good on paper—if Federal efforts are serious about passive solar as a viable energy alternative. Otherwise, passive solar systems may be limited to the small custom built home market.

Mr. MOSS. Mr. Greene.

Mr. GREENE. Thank you, Mr. Chairman.

Professor Noll, let us turn briefly to the tables which you presented to us earlier. I will work off the documents which you provided the subcommittee. As I understand the documents which you presented to the subcommittee, what we are doing here is comparing the costs of a variety of traditional sources of energy and heat with a specific type of passive solar building which has been validated throughout a number of climatic regions. If a consumer or we as a society were to try to make a judgment between the purchase of a unit of energy at a replacement level, and fossil fuel energy versus an investment in passive solar, which of these tables [see p. 52] would most accurately reflect the economics of that kind of a judgment?

Mr. NOLL. I would say the heating oil fuel alternative. The reason for that, first of all, is that I am using a life cycle concept here. I have down here the conventional cost in dollars per million Btu of the heating oil fuel alternative.

Because of the current entitlements program, the cost per gallon, let's say, of heating oil is very similar all throughout the country. The range is not very great, as it is in natural gas, where you have interstate markets and intrastate markets.

A certain escalation rate was assumed to arrive at these figures here, and that escalation rate was 3.5 percent real increase over and above the rate of inflation per year.

Now, to the extent that the price is in a two-tier system in the United States, and this produces a domestic weighted average price that is lower than the world price, the average cost of crude to the refiner in the United States is actually less than the world price.

If you want to look at the differential between that and what the actual world price is, it is about \$5, \$4 to \$5 per barrel.

So, to the extent that heating oil produced domestically is priced below the world price, the economics in terms of passive is good. But when you do go to the replacement price which for oil we can take to be the world price, the economics indeed do look more favorable.

Mr. GREENE. So then if I understand your table correctly, if a rational consumer with the appropriate amount of information were to make a judgment between passive solar and the replacement cost of a unit of fossil fuel, in that instance his or her home would be passively heated to the extent designated in your column marked solar fraction; that is, if I were a rational consumer in Los Angeles facing the world price for oil, or the replacement cost of energy, my home would be 60 percent heated passively, in Cleveland it would be 20 percent, and in Madison, Wis. it might be approximately 45 percent passively heated.

Now, as I understand the policy difficulty which you have suggested to us, and Dr. Hirshberg has suggested to us—in order to protect consumers from price gouging by major oil companies, we have put into place a system of price controls on oil and natural gas. That, however, does not at the consumer level reflect the replacement cost of those fuels. As an alternative to deregulation we can set our tax policies so that the gap which would have existed between the cost of the passive solar investment versus the

cost of the replacement barrel of oil or other traditional fuel at the replacement level can be recreated, without gouging consumers, is that correct?

Mr. NOLL. Yes, I would say that is correct.

Mr. GREENE. Okay. So then in your judgment, should we be moving in the direction, then, of providing financial incentives which reflect that kind of policy?

Mr. NOLL. I would say there are two things—I would like to give a little background, first of all, to this question.

When we invest in a passive solar system of, let's say, some substantial size, not just additional window area, but you do want to integrate thermal mass, we cannot do it for free. It costs dollars out of our pockets.

Now, supposing I am building a new home and I want to put in a passive system that costs \$5,000. If I am a middle income person, it may be that the mortgage payment without the passive system is already up to my income limit; in other words, I cannot get any additional loan. So, I have to come up with the total amount in cash. A tax credit would help there.

Another alternative, of course, is to be able to finance the initial capital investment at a lower rate of interest that enables me to tack on an additional amount to my loan.

So, there are two ways one could go. One could give a tax credit, which is a dollar rebate, right off of your tax liability, and if that is refundable I could get an amount greater than my tax liability.

Or, you could set up a system of low interest loans that improves the financing capability. In terms of the economics, you can set up the two programs to be identical for a rational being, but the psychology, perhaps, is different of the two programs.

Mr. GORE. Would counsel yield briefly.

Mr. Noll, what kind of new mortgage instruments might be helpful in this regard?

Mr. NOLL. Some new mortgage instruments have been introduced in California, as I understand it, and this is called a graduated mortgage payment. The way traditional mortgage payments work is to take a capital recovery factor, or to take an interest rate, compute a capital recovery factor which amortizes the cost of the additional loan over the life, let's say, a 25-year life.

That dollar amount is equivalent in current dollar amounts, let's say \$300 per month. I pay the \$300 per month, year after year, but as inflation occurs, the real dollar value of that amount is declining over time. So in 1978 dollars I am paying a lot more for a mortgage now than I would be in the 25th year, assuming that my income rises with the rate of inflation.

The effect of this is to tilt the mortgage payments in such a way that it distorts decisionmaking. An alternative which is offered by the graduated mortgage payment is to start the interest payment off at a lower value and let the mortgage payment rise over time.

What this does, this implies that your mortgage payment is now a lower fraction of your income, and therefore you can take on a greater loan. You can loan right up and include the passive system in the very beginning.

I believe this is a unique thing and very helpful, not only to passive solar, but to the home building industry in general.

Mr. GORE. And it would be particularly appropriate for passive solar because the long-term savings of utility costs would enable homeowners to keep up with the accelerated principal payments.

Thank you.

Mr. GREENE. With respect to tax credits, one of the things which arises in your tables is that even with respect to the natural gas alternative, some passive solar appears to be economic today.

Should we take from that information, the notion that we should not support passive solar with financial incentives of one kind or another?

Mr. NOLL. No, I would not arrive at that conclusion. The reason is that if the consumer were receiving the proper signal, he would then have an incentive to size in a much larger system.

A much larger system size means greater energy savings, less imported oil.

So, we are in a situation here, where I have shown on a life cycle basis, that it is marginally competitive against natural gas.

Now, to the extent that the consumer is not rational, as we have been talking about here, to the extent that a person does not have a 30-year time horizon, to the extent that there is very much uncertainty as to what the price of natural gas in the future will be, his decisionmaking will not follow a life cycle costing logic.

He may have notions that prices will be increasing and that he had better do something. But still, when he is looking at current costs today, natural gas does not cost him that much.

If you do give them, on the other hand, this incentive, it can correct for that deficiency and can correct for the signals that are causing for a distorted decision, not to invest in energy conserving technology, passive solar being one of them.

Mr. GREENE. OK.

Mr. Witwer, if I may direct some questions to you. You mentioned in your prepared testimony that there were a number of problems with respect to organizational confusion in the Department of Energy as they related to this particular program.

Do you see those problems as still existing, and what should we be watching for?

Mr. WITWER. I would say that basically I think it is too early to tell. There is a lot of startup that is still going on in DOE. I think that that has been aggravated by the fact that they have not had a permanent Assistant Secretary for Conservation and Solar Applications, until recently.

So, I think basically it is too early to tell, and we will have to see over the next year how things work out.

From what I have seen over there, there is a lot more interaction between the people that do building conservation programs and the people that do heating programs than there was under the old ERDA structure, but I don't think we can tell just yet how this will work out.

What is needed is in all of the continuing hearings of authorization and oversight, that those things need to be brought out, and we need to hear from public witnesses to see whether or not people feel that they are being sidetracked or not getting the right kind of programs through.

Mr. GREENE. Mr. Witwer, in the Stanford Research Institute's study, through your weighting process you determined that a number of programs with vastly different levels of promise to consumers in the reasonably foreseeable future were getting essentially the same levels of funding or on a few occasions programs with less promise than others received more funding.

Could you make a similar sort of comparison between the solar budget and other portions of the Department of Energy's budget?

Mr. WITWER. The charge that was given to the solar working group was only to look at solar alternatives, and to compare them with one another, to check the balance in the solar program. So, on the basis of that analytical work, I cannot make any specific conclusions.

Although I would say that work having been done, there has been a lot of talk and we have looked at and thought about some of the other things. Although we don't have any firm analytical basis to make those comparisons, I could point out to you some comparisons that might be interesting or at least some areas you might want to look at.

There are a lot of parts of the DOE budget that have been funded at a higher level than the solar program. An example of that that I would use is the fusion budget.

Now, in the request that was made to Congress from the President, the fusion budget request for 1979 was, I think, \$330-some million for magnetic confinement, and another \$120 million some dollars for inertial confinement.

So, the budget for fusion was somewhere in the area of \$450 million, budget request.

Now, most people feel that fusion, is unlikely to be developed for at least 20 years. There are people that will say it is 30 to 50 years, and there are people that will say it will never be economically feasible, or even work technically.

So, there seems to be a program that the Government is putting hundreds of millions into, and that might go on for 20 to 50 years.

Mr. GREENE. How would that compare to the present passive budget and the total solar budget?

Mr. WITWER. The total solar budget in past years has been in the area of \$300 to \$400 million. Of course, the 1979 budget has not been set yet.

The budget request was on the order of \$300 to \$400 million for all the solar technologies.

I think the point is that some of those technologies, such as passive, are things that could be greatly accelerated in the near term, we could see some results from them now, not in 20 years or 50 years. We could see some impacts of them within 5 to 10 years.

Now, Dr. Balcomb pointed out that even if we do a lot of passive solar heating we might only get half a quad or a quad of energy by the end of the century and that could be true, but the point is that is something we could do, and it is unlikely we will get that much from fusion in that same time period.

I would also add that in the authorization process in the House, the passive budget that was acted upon by the full committee showed a substantial increase in commercialization efforts in the passive area.

So, the House has taken the steps to accelerate that program significantly.

I think what we will have to do is look at the results of that program for 1979 and perhaps there could be even more activity in that area in 1980, then.

Mr. GREENE. I have some questions to you, Mr. Hirshberg.

You are our man with practical experience, and the person who may suggest to us some of the real world problems we will run into with respect to this technology.

One of the first which springs to mind, as I reviewed your prepared testimony, was your indication that we have some institutional biases perhaps being focused in the Office of Management and Budget.

You indicate there is a stress on research and development to the exclusion of commercialization. Could you elaborate on that? Indicate what the effect of that exclusionary policy is?

Mr. HIRSHBERG. I think it is a bias that is institutionalized in the way in which I think budgets are accepted and passed on in the policymaking process.

I think it is something that runs rather into the tradition of the way we have approached policy in this country, probably over a number of years, where the Federal Government has traditionally focused only on research and development and not particularly on commercialization.

The notion I think had been that once you developed a better mousetrap, the world would beat a path to your doorstep.

I think there are a number of specific instances where that has proved to be false, and these small but very useful technologies, such as solar passive and active water heating and inexpensive active space heating, are good examples of that.

I think, therefore, the Federal Government needs to move beyond its traditional role and look at ways of bringing about early and rapid commercial use. Only through this are we going to achieve this one-half quad or three quad or five quad saving by the year 2000.

Now, the problem is, as I understand, or the sort of way the process works, is that the OMB rules, or the OMB set of operating procedures works to the detriment of any spending in the commercialization area.

Essentially they are only in favor of spending money in terms of very hard research and development. They do not want any funding beyond that. I think that is an institutional bias that has to be reexamined in the light of the evidence and the requirements of the energy crisis itself.

Mr. GREENE. Then we may very likely have a situation in which we have relatively proven technology which just doesn't go anywhere.

Mr. HIRSHBERG. Which doesn't go anywhere because there has been Federal effort made to develop some new research designs, improved research designs, now no Federal effort to really get those designs out there.

When you deal with the building industry you are dealing with a very disaggregated industry. Less than one-half of 1 percent of all new buildings are built by the largest builder. That is very differ-

ent from dealing with the automobile industry, where you have four large manufacturers.

The building industry is very disaggregated and very fragmented. You really need to go beyond the traditional research and development. You have to deal with that infrastructure, deal with that wide variety of players in the building industry process.

Mr. GREENE. That being the case, what particular actions would you suggest to the Congress and to the Department of Energy with respect to moving ahead in dealing with those rather disaggregated constituencies for information?

Mr. HIRSHBERG. I think there needs to be more stress on developing information programs to get to the right person in the chain. I think for active systems this has begun. I think that the AIA has been involved in this, and other groups, that are the equivalent of the right industry group to do this.

For passive solar I am not convinced that we have even really begun to look at this because I think we have really sort of ignored passive solar frankly until very recently. I think that the chain is likely to be different, the delivery chain for solar systems, than for active systems.

I am just stressing the need to do the research to understand how to get that information out there, rather than being able to give you at this point any specific recommendations in that regard.

Mr. GREENE. It is true, is it not, that the industry itself is dominated by builders, small contractors, who will provide in the aggregate somewhere in the range of 70 to 90 percent of the homes built in America, which is, as I understand from Dr. Balcomb, the class we are really focusing on.

So, from that fact, certain policy initiatives arise. We would be focusing our information efforts on people not incredibly sophisticated about building, who do not typically turn to an architect.

Mr. HIRSHBERG. That is right. I am concerned about that. I am less sanguine than Mr. Noll or Dr. Balcomb in terms of the building industry to pick up even on what are economically desirable passive designs.

I think that the building industry—the builder is typically concerned and dominated by his particular financial concerns, which is scheduled. Once his project starts, the matter is ticking, he doesn't want to fool around with anything new, anything different.

He wants to get his project up and built and sold and anything that interferes with that process increases his risk. I think, therefore, that the tract building concept—to assume the passive design is going to be widely used by tract builders easily is I think false.

There needs to be, therefore, Federal efforts that specifically deal with training and education of tract builders, that deal with this site variation problem, and the different costs of coming up with passive designs that have variations, that are allowable variations in terms of site design.

I think those programs haven't even really begun. I think those should be funded.

Mr. GREENE. So there is a need to focus on that particular group of decisionmakers inside the building industry?

Mr. HIRSHBERG. Yes, and that, of course, only gets at the new buildings. I think there is substantial promise that others have

talked about with sun spaces and other kinds of retrofitable designs. That is where a large market exists.

I think there needs to be more research and development in terms of justifying those kinds of designs from a technical point of view and then looking at the chain in which those designs might get out there in the marketplace and utilized, which again would not involve the builder, for instance. It would involve typically a contractor who does remodeling, for instance, or maybe an architect.

Mr. GREENE. Thank you, Mr. Chairman.

Mr. MOSS. I think we are engaged in a very interesting discussion. But we have not identified the hard issue. We are dealing with a system already in place, a Federal system.

I think we have to carefully define the proper roles of the Federal Government, the States, counties, and the cities. Perhaps in no other industry is it as significant as in the building industry.

The enormous influence of local government, the regulatory pattern which has evolved over the past two centuries of the Federal system, have created problems that are not resolved by a change in the attitude of the Office of Management and Budget.

Within the framework of the Federal system there are only certain things that OMB can do if it tries to do everything. I think those have to be identified.

We have limited areas of insuring financing that would permit some Federal intrusion, although the Congress has repeatedly stated—I recall when former Secretary Romney, of Housing, encountered difficulties because he tried to go beyond the limits of the congressional concept of what that system should continue to be.

So, I think we must address the question of the appropriate Federal role, what is it. How can it function to bring about the objectives that you have in mind, the more rapid assimilation of technology into the commercial scheme of things.

Which finally means you have to get it in the house, either a retrofit job or a new house.

We have no role at all in the approving of subdivisions.

Mr. HIRSHBERG. I agree with what you are saying. In fact, it is the Operation Breakthrough experience that Romney was in charge of that I think makes me very cautious with the building industry simply picking up on new passive designs and widely using them.

My point is that from a policy and program point of view, as you develop passive and active solar designs that make sense economically, it seems to me you need to develop in addition programs that may very well involve State and local activities, to get these designs out there and disseminated and utilized.

Mr. MOSS. How is that done?

Mr. HIRSHBERG. There are a number of different vehicles for doing this. The NEA, for instance, that I think is still pending, calls for State plans in terms of conservation programing, with the Conservation Service utilizing utilities.

I think the utilities represent a potential resource in terms of getting information, and potential solar designs out to users. I think that is one way.

I think dealing with the code official, training programs and education programs for him would be good. It is very well to say we are going to have performance codes and place on his shoulders—and he is not very well trained—the problems of interpreting these performance codes.

But in fact he wouldn't be able to do this unless somebody helps him. I don't think the States have the resources to do this. So, the Federal Government could provide the resources to the States, who in turn could help train the code officials in these matters.

Mr. MOSS. Is it true that States don't have the resources? At the moment the largest accumulation of surpluses in the Nation is in the hands of the States and not in the Federal Government.

Mr. HIRSHBERG. I think the largest surplus has disappeared with Proposition 13, but it is true—

Mr. MOSS. That one continues to be a vigorous surplus that mounts as the days go by. But we don't know quite what it is going to be.

Mr. HIRSHBERG. There are certainly surpluses in California and Texas and a few other States. But I think by and large there are not surpluses. Even so, the programing activities at the State level, even in energy, seem to be from my perspective, are—in the 48 contiguous States—much less capable than the Federal efforts, with a very few counterexamples, and California is one of them that has been a very active State.

Mr. WITWER. Mr. MOSS, I would like to add a comment to your question.

Mr. MOSS. Yes, indeed.

Mr. WITWER. About the Federal role. I think an interesting analogy can be drawn with the success of the Federal Government's program in automotive fuel economy. It is interesting that the Government has stepped in and assumed some responsibility on the part of the consumer for automobiles, which is a device that can cost \$5,000 to \$10,000, and people will burn a few hundred dollars worth of gasoline a year.

The Government sees to it that the people get some information about what that is going to cost by an EPA mileage standard on the car. In addition to that there is also the mandated fuel economy standards, and the fleet average stuff, which is a part of the national energy program.

The point is the consumer gets a lot of information on that.

Now, it is ironical in buying a house, which is something that costs \$100,000 or more, and people are experiencing fuel bills of thousands of dollars a year, they have no guidance on which to base a purchase decision.

Many studies have pointed out that the most effective Federal program as far as reducing energy consumption that we have come close to enacting is the automotive fuel economy standards.

I think that a similar kind of program for housing could be equally effective.

Mr. MOSS. Let's examine, though, the characteristics of the automobile and how we were able to act, and the home. The automobile is highly mobile. It is clearly in interstate commerce. We acted preemptively to override any State statute. The Federal standard became the standard for the entire Nation.

Now, I assure you that that is not a possibility in housing, not in the foreseeable future. If this Congress was to seriously consider a standard preemptively dealing with housing we would encounter a fury that we would not be able to contain.

So, it is not practical as an approach.

Clearly it would be more efficient, and clearly it would give us an opportunity to move more quickly, but it cannot be done realistically.

The difference in the two products is too pronounced.

Mr. WITWER. I guess I would just say anything that can be done along that line. It might be to encourage States to do that. For example, this might be able to be done in the context of the requirements for State energy plans.

Mr. MOSS. States can do it. As the experience in Davis, Calif. shows, cities can do it. So that we have in this Federal laboratory an opportunity for a variety of methods to be explored, and try to promote those that prove the most effective.

But for the Congress to do it initially becomes a much more difficult undertaking.

Mr. HIRSHBERG. I understand and appreciate the problem of the Federal prerogatives here, and the stepping over the boundary. I think the boundary, though, is a bit murkier at least the way I see it.

The NEA does in fact intrude on what has been a traditional State right—namely, control of the utilities—and does mandate utilities to do certain things. I would be rather amazed that States have not gotten very annoyed about this.

I don't know under what power the Congress has developed that portion of the NEA, but clearly it is in the NEA. I think that coordinated programs with the States, providing money for specific purposes in terms of planning, in terms of the idea that Mr. Witwer brought up, and other ideas, probably would be successful.

States would be responsive to this. I think they look to the Federal Government for leadership.

Mr. MOSS. We have made a rather strong case for Federal movement into the energy field because of the interstate characteristics of most energy, particularly that which is electrical energy, whatever the source of generation—it moves through interstate systems that are very much in interstate commerce.

So that there is a stronger claim of jurisdiction than I can think up for housing, or the monitoring of subdivisions, and that becomes very important, as we have seen from material submitted here today—the designing of the subdivision becomes an important matter. The setback requirements become very important.

There are many aspects of it that are controlled completely by local government. We can advise if you can tell us how to do it effectively.

Mr. GREENE. Just to quickly summarize, Dr. Hirshberg, as I understand it what you have told us today is that commercialization efforts with respect to this particular technology have to date been inadequate.

Mr. HIRSHBERG. Yes; that is right. That is my opinion.

Mr. GREENE. And that with respect to future commercialization efforts, a substantial portion of those efforts should be focused upon the small builder, the tract builder, would that be correct?

Mr. HIRSHBERG. And retrofitable systems. I think that has to be done in concert with increased research and development and demonstration funding.

Mr. GREENE. Thank you.

Mr. MOSS. Mr. Gore?

Mr. GORE. Thank you, Mr. Chairman.

Mr. NOLL. I have looked carefully at the table that counsel reviewed with you. I think this is one of the messages that needs to be given to the American people, that the economics of solar energy, passive or active, can look very different depending upon what fraction of the total energy demand you wish to assign to a solar technology.

You pointed to the heat oil trade-off. We have looked at some computer programs for electrical heating in the specific area of middle Tennessee and came up with a similar trade-off, that solar heating, space heating, that is, can be economical today for between 35 and 40 percent of the space heating requirements.

For solar hot water heating the figure runs up to 75 to 80 percent.

Are passive systems, in your opinion, economic around at least the 40-percent range throughout the United States? Or is that a generalization that one shouldn't make?

Mr. NOLL. I would agree with that statement, against the electric resistance alternative, very definitely. Even if one looks at an \$18-per-square-foot national index cost—but at \$18 to \$20 per square foot, it competes, I would say, in at least 90 percent of the States, of the contiguous 48 States, against the electric resistance alternative.

Mr. GORE. That message is a very powerful one that simply hasn't gotten across. It contains a few complex assumptions. One is that the lifetime cost is what the rational buyer will look at. Second, an inflation factor for conventional fuels, which is eminently rational to assume.

What is the payback period for passive systems, typically?

Mr. NOLL. Again, it depends very much on what type of system we are talking about, and its size. But as I have shown in the table here, against an electric resistance alternative, and a Trombe wall which is a fairly substantial system, they run around 8 years, on a simple payback basis.

Now, on a greenhouse, for instance, it could be 1 year.

Mr. GORE. What about with a tax credit?

Mr. NOLL. With a tax credit I would say you can lower the 8-year payback, assuming the same sizing, with a tax credit down to perhaps 4 to 5 years, and that is substantial in terms of the consumers.

Mr. GORE. It certainly is. I invite any other members of the panel to respond to this next question.

Have you been able to identify any effects of the continued delay in implementation of the solar tax credit?

Mr. NOLL. There is some talk—and maybe the other members of the panel would be more qualified to talk about this—but the

continued delay in the legislation is introducing uncertainty into the solar market, and especially in the active solar market.

There are a lot of small businessmen, a lot of small solar manufacturers and installers who are very constrained by cash flow problems. If a consumer is sitting on his decision, let's say on a retrofit decision to put in hot water, even, for the tax credits, he is going to wait.

If he knows the Federal Government is going to come out with a sizeable tax credit, why don't I wait for that. If it is made clear, perhaps, that it would be a retroactive—it is retroactive to all systems put in, that would be put in now, and that was made clear to people, perhaps that would not happen.

As far as I can understand it, this risk has hurt to a certain extent the active solar industry. In terms of passive, it is not written into the legislation now, so I cannot say what that effect would be.

Mr. HIRSHBERG. We have just completed an initial study of this in six regions. We have definitely found that kind of effect, particularly in the last 6 months. I think for the previous 6 months that has not been a factor.

People had felt that the tax credits were going to be enacted into law, and they would be retroactive to April 20, the date of the President's message. Now they wonder whether it is going to pass at all and the sales have fallen way off.

Mr. GORE. Those of you who are expert in this business, this technology, are telling us that we are making a mistake in delaying much longer or any longer in the implementation of retroactive tax credits, if we seek to accomplish our goal of stimulating the introduction and acceptance of solar technologies.

Mr. HIRSHBERG. Yes, I agree with that. It is the marginal small businessman who is probably getting impacted most. The larger businesses are able to absorb this temporary problem. Many of them are standing on the sidelines anyway, but the small businessman out there, who has put his savings into this, is really hurting at this point.

Mr. GORE. Let's talk about the small businessman for a moment, Mr. Hirshberg.

Do passive systems lack the product opportunities that active systems have?

Mr. HIRSHBERG. Well, that is a difficult question to answer. I think maybe for small business passive systems actually have more opportunities, for the small businessman than the active systems, which I think are more amenable to manufacturing processes and therefore economies of scale associated with large manufacturing production lines.

I think there is a lot of room for the small businessman in the passive solar energy industry.

Mr. GORE. Dr. Balcomb, do you want to comment on that?

Dr. BALCOMB. Yes. I believe there is a general feeling that there are not product opportunities in passive solar, and that that is entirely a wrong statement, that there are many product opportunities. I will try and cite a few.

The whole area of window assemblies is a very important one. We need to have window assemblies which are manufactured,

which have movable insulation systems and movable light controllability into them.

Such systems have been built in Europe, and developed to a fairly high level of technology in one particular design concept. They just don't exist in this country. It is a big business there.

The glazing industry and the masonry industry in this country already dwarf the solar energy industry, and their product opportunities in passive solar are enormous.

Mr. GORE. Are they taking advantage of them? Do they recognize them?

Dr. BALCOMB. No. I see very little indication. The masonry industry has begun to say, "Gee, this energy conservation is going to hurt us because people won't build masonry buildings because masonry has poor insulating properties."

So, they are running a little bit scared. The glass industry sees building codes are cutting them out, and so they are running a little scared. But they don't realize that passive solar provides the opportunities for turning that around.

This is a huge industry, in place, fortunately, and they should get with it, in my estimation, and promote this within themselves.

There are other examples that should be cited. If glass could be made to have an energy loss coefficient of half of its present value, which can be done—and I have seen examples of such glass manufactured before—that would further revolutionize the passive solar application because it would make it that much more energy effective.

The only way to do that, though, is to get the glass industry itself interested in accomplishing this.

Mr. GORE. But as far as the design itself is concerned, the product opportunity is not there, it seems to me. Architects are interested, I believe, in incorporating these new ideas into what they have to sell.

But the impact of architects on the building industry is really quite limited. I think that is unfortunate in a way, as a former home builder myself. It is just easier, though, to get one of the prefab designs out of one of these books and put it together.

That is the market that we have to penetrate, and we can't rely on private enterprise to do that, or can we, because there is not the product opportunity.

Mr. HIRSHBERG. This is one of the points I was trying to make. I would hope that Federal research could come up with what we would call bolt-on systems, for instance, to retrofit, that might in fact generate a product opportunity, if you will.

I have the same concern you do because I think in general right now passive is really a design feature, more of a design feature than a specific product.

Mr. GORE. Do you want to comment again on that?

Dr. BALCOMB. I will give you an example.

The architectural journals and the building trade journals today are full of ads for various window assemblies. It is one of their major advertisers.

You will not find in any of those cases that the ads say that you should use windows because it will save energy in the building.

They avoid the issue of energy because the general consensus is that windows will lose energy.

So, they talk about esthetics and everything else. In fact, if they knew to push that aspect, it could turn around a general trend to use less windows—if they were properly placed in conjunction with the proper mass in the building, they will enhance, as I have indicated, the energy characteristics of the house.

But that industry, with that product, has not done that.

I don't know how you turn that around.

Mr. GORE. Could you describe, Dr. Balcomb, the effect of New Mexico's solar tax credits? We have been speculating on what the impact will be at the Federal level and the problems we encounter by continued delay. But New Mexico has already enacted such tax credits.

I am wondering if you could outline briefly for us what effects you have been able to identify.

Dr. BALCOMB. The New Mexico tax credit has been in place for nearly 3 years now. It provides a 25-percent tax credit up to a total of \$1,000. There have been several hundred credits given to date. New Mexico is——

Mr. GORE. Just several hundred, that is all?

Dr. BALCOMB. Yes. New Mexico is not a very populated State, to begin with. So, I think that represents a significant impact. In fact, nearly 10 percent of all of the solar homes in the country are in New Mexico. The per capita incidence of solar homes is manifold greater in New Mexico.

There is a tremendous enthusiasm about this, and an awareness within the State exceeding that of any other State, except perhaps California now. We also have a tax credit in the State of California, which is much more recent, but a 55 percent tax credit.

Both apply to passive systems. I don't think it is any coincidence that there are far more solar homes in these places than there are in other localities.

It all contributes. In some localities, 30,000 people in New Mexico, in Taos, a quarter of all of the new homes that have been built in that community since 1975 are solar homes. That is a pretty impressive figure.

Mr. GORE. Yes, I would say it is. It surely is.

Dr. BALCOMB. They are very aware.

Mr. GORE. Mr. Witwer, how would you compare the relative potential of passive systems to the other solar technologies?

Mr. WITWER. To the other building heating technologies?

Mr. GORE. To the active systems.

Mr. WITWER. For certain building types, I think it can be equal or perhaps even greater. Especially I think Dr. Balcomb in his testimony indicated that for low-rise buildings, and even for some high-rise buildings, you can certainly apply passive techniques to nearly all buildings.

I think we will find as time goes on, as technology improves, as prices go up for other fuels, there will probably be a tendency toward putting more active components on buildings as opposed to passive principles.

So, we will find initial buildings will have a lot of passive principles. As time goes on and active prices and performance improve,

we will find the shift going more toward active things because it will be more economical to put more hardware on the building when energy prices are higher.

I think both of them are going to be important. Active systems for one thing are important because if you look at say water heating, it is very easy to retrofit water heaters, and in a lot of buildings, that can be an economical and efficient retrofit device.

So, they are both important. I would say the importance of passive especially is in the near term. That is why the testimony by Alan is so important, about commercialization programs, because passive principles are here, we can use them, and we need to get them out.

I think we will find those things are practical right now, and later on we will get more active things.

Mr. GORE. But our budget priorities don't reflect that.

Mr. WITWER. The emphasis has been strongly on active programs. I think in my testimony, as I tried to indicate, part of the reason for that is that with an active system you can see something, you can count square feet of collectors.

It is not quite as exciting to show somebody that what you have done is that you have put some homes out there that have a masonry wall, or you have moved some windows around on them. It just doesn't look the same in terms of what is happening in the program.

Mr. GORE. And I think your point is a good one, that passive solar technology has fallen between the cracks, between active solar on the one hand and conservation on the other. It is left without a home.

Mr. WITWER. That is right. That also ties back with the original comment. Not only does it lack an organizational home in the Government, but it also lacks to some extent a natural constituency in the industry.

It is not like what has developed in the active area, in which you have people who want to produce and sell these things. A lot of solar technologies flounder from that lack of a natural constituency.

I think, for example, wind has been that way. I am just saying that is a problem. Another problem like that is patent protection. Business cannot get themselves protected with patents, and so it is hard for them to really invest a lot of front-end money in developing the things.

Mr. GORE. Well, I hope that Miss Walden can turn those priorities around. I have talked to her at length about this. She was one of the participants in the workshop I referred to earlier. I hope that she keeps her awareness and is able to give it to others within the Department of Energy.

Mr. Noll, what would you estimate to be the potential effects of passive systems on employment?

Mr. NOLL. That is a very good question. There was a recent study in California which dealt with this, and they showed that the employment effects of the passive solar energy were more substantial, as opposed to other types of perhaps more capital intensive technologies.

I must admit that I am not too familiar with all the assumptions behind that study. I have not read it in detail.

I would like to make the comment, however, that you are talking about a building industry, and not only the material network with masonry and glass, but you are talking about labor skills, also.

Because when you are designing a passive home, a lot of the labor is nothing specialized. It is labor that already exists. For this reason, I think—I am not sure from that standpoint whether you will increase the labor impacts.

But to the extent that there is greater demand within the masonry industry, for window assemblies, or opportunities for small manufacturers to come up with night insulation concepts, new storage concepts, things like this, I think there is a good opportunity there for increase in employment.

Mr. GORE. Well, thank you very much.

How do the maintenance costs of passive systems compare with conventional systems?

Mr. NOLL. Conventional heating, ventilation and air conditioning systems?

Mr. GORE. Yes.

Mr. NOLL. In a passive system you still require a backup. In other words, in very few places would you like to rely upon 100 percent passive solar heating. So, your conventional electrical resistance heating, or natural gas furnace, heating oil furnace, or boiler, whatever, would still be in place.

So, you are not going to avoid any maintenance costs by not having those in. They will still be there. So, the question is by putting in the passive component, how much additional maintenance will you have over and above what is already there for the backup.

Experience to date in the buildings that are in place have shown where the system is not automated to a high degree, which in many instances they are not, there is almost zero maintenance. It depends a lot on the glazing, what type of glazing you have.

Most people put their fiberglass or acrylic type of glazing, and things like that, breakage is not a severe problem. If you put in glass, breakage could be a problem, but no more so than a normal home.

You have more glass and perhaps the risk is greater of breakage.

So, I would say the operation and maintenance in that respect is very small. The requirements are very small.

However, if we look at automatic movable insulation devices, which I think are desirable things, they may jam up, they may have problems with those.

So, I cannot sit here and honestly say no, there are no operation and maintenance costs. That is a very important part of passive systems. If you are going to gain the heat, it doesn't do you any good to let it all go back out again, so you do want to save the heat to the best of your ability.

To the extent you do this with automated equipment, that may introduce additional operation and maintenance costs.

Mr. GORE. Are you familiar with the sky lids now on the market?

Mr. NOLL. Yes. The sky lid was developed by Zone Works in Albuquerque, New Mexico. This is a basic system where you have

freon within a lid, and what it essentially does is when the Sun shines upon it, the freon vaporizes and it runs to one side of it, which weights down the lid, and it automatically opens up.

When the temperature cools off in the nighttime, the freon again condenses, the flow goes the other way, and it closes it automatically. This is a totally passive and very unique and very nifty night insulation device that requires no maintenance at all.

Mr. GORE. No maintenance at all.

Mr. NOLL. I would say very little. There are manual overrides that you can do. Would you like to comment on that, Doug?

Dr. BALCOMB. The sky lids have been placed in many buildings. I would just observe that the Aspen Airport example, which I showed, has such a system for providing night insulation.

Mr. GORE. Mr. Hirshberg, did you want to comment on that?

Mr. HIRSHBERG. Not on that particular example, no.

Mr. GORE. Mr. Hirshberg, how do you feel about HUD's passive design competition and demonstration program?

Mr. HIRSHBERG. I don't know about that program in detail.

Mr. GORE. Do any of the other witnesses have a familiarity with that program?

Dr. BALCOMB. Yes. I participated in at least one meeting when this was being formulated by HUD. So, I am familiar with it and will be involved in the review of proposals that have been submitted in response to that solicitation.

It was specifically targeted toward passive systems, and we tried to structure it so that we would get a response from the community in the country that knows how to design such systems, make it attractive to them so that they would submit proposals.

My understanding is that there has been a very successful number of proposals submitted; that is, there are quite a few to evaluate, several times the amount of money available to give awards. So, people have responded.

Mr. GORE. In light of that, should it be expanded?

Dr. BALCOMB. I believe so. I think the idea of having specifically targeted areas is a good one. You can write the solicitation so that it emphasizes that area. We might in the future see solicitations which are targeted to particular geographical areas.

It has been suggested that those could be run through the regional solar energy research institutes.

Another possibility is to target toward small or light commercial buildings, whereas this one was strictly for residential—there is no good reason why these technologies are not also applicable there. There are other possibilities. I think it is a good mechanism.

The architectural community in particular is used to the design competition situation. They like to respond to those.

Mr. GORE. It is fun.

Mr. Hirshberg, do you believe that there is a lack of training for the design and installation and maintenance of passive systems?

Mr. HIRSHBERG. Yes, I think there is. I think that there needs to be more information out there to the people who are going to use it. I think architects are reasonably well familiar with this because right now it is a design feature.

But your average builder I don't think understands the technology or can relate to it very easily.

Mr. GORE. Mr. Wunder?

Mr. WUNDER. Thank you, Mr. Chairman.

I would like to ask a question of Mr. Noll, in relation to your chart. My problem goes to—is one of the problems here the mobility of society.

Now, taking your best case for a passive solar system, which would be the electric resistance fuel alternative, the minimum payback time on your chart is 8 years. Yet, the data shows that most people move every 5 years.

Now, I have talked to my neighbors, for instance, about putting in a heat pump. The almost immediate reaction I get is it will take me x number of years to pay it back, and I don't intend to be here that long.

Second, let's assume that you put one in—build a house or get a house built with a passive system in it. Is there too a hesitancy that that may not be marketable at some later point in time? There may be advanced technologies come on to the line that makes this obsolete? Or even if it is not obsolete, whether it will sell.

Again, I cite a personal experience. Three houses down from mine is an active solar system house. It has been on the market longer than any house in the area. It just sold. It is a new house. It was on the market almost 20 months. Other nonsolar houses have sold much more rapidly.

I was wondering if you might comment on those aspects, or any member of the panel.

Mr. NOLL. Yes; that is a very real concern, and a very important comment that has been made by a lot of people. I would like to mention one thing that I consider to be very important, and that is that in passive solar architecture and design—a lot of people talk about systems, but it is really an art.

It is an integral design, a system of natural architecture. In some cases active components are tacked on. They are something you could conceivably remove, unless they are integrally combined with the roof.

Now, to the extent that a person puts in a passive system, and that the system, I assume will work quite well, and the person can actually give verbal testimony, which many people, in fact most people that have passive solar residences will attest to, their ease of operation, living in them is very comfortable—that right there can be a strong selling point.

In addition, as people get more and more concerned about energy costs over time, they are not only going to look for houses that are heated by passive, but also ones that use smart energy conservation, which should be a part of the system of natural architecture.

In addition, since passive solar is integrally designed, it may be in fact that as energy prices increase over time, that that addition is viewed as—it will be capitalized into the market value of the home itself.

So that the person that sells it, even though it is not paying itself back, he can recover the cost in the sale price. It may be a very attractive item to the person buying it.

Mr. WUNDER. But yet, so much of your thinking is prospective, in terms of what the situation is going to be 5 years from now. We are talking about something that is happening today.

The lines have not crossed, as is evidenced by your own charts—where the economic factors are seemingly sufficient, given what I said about the mobility of society, and what have you, that people are induced to get into this.

You make these architectural arguments. Some people may find those types of houses to be attractive, but I think the primary motivation for doing it would be to save money on your utility bill.

If you went into one today—this is what I have heard a lot of people say, about active solar systems—they have looked into them, but they don't want to get into it right now. They are not sufficiently well-developed, and there is research going on to improve them, and they are going to wait a while.

Mr. Noll. I would say there is no doubt about that. But I think as evidence to date indicates, there is a lot of difference—I mean, this is not true across the board. There are some very cost effective systems in. But there are a lot of problems with a lot of the space heating systems.

I don't think anyone would argue that domestic hot water is a very viable alternative today. I think when we are talking about space heating, you get into additional problems.

The economics of passive are such that it costs you nothing to buy yourself in. In other words, in an active system I need a large storage, I need additional ductwork, I need additional controls.

A portion of those have nothing to do with the collector areas itself. It is a fixed cost that one has to pay before they can get any heat out at all.

In a passive system, one can do very little and get a return on it. He is not stuck with that heavy fixed cost component.

Now, to the extent that you put in perhaps a very unique design in passive, it may very well be that it won't sell. I don't disagree with you. That could be a problem. But I think the maintenance problems that we have found in active will not be nearly as severe in passive.

I think the economics in addition are more favorable for many types of passive concepts.

I don't know if that answers your question.

Mr. HIRSHBERG. I would like to comment on that because I think that is one of the key questions which has to do with the way people make purchases and what influences those purchases.

I don't think we fully understand all the factors in that decision process. We are doing a study of that now in some of the selected markets with respect to solar for that very reason.

It certainly appears that homeowners require 3- to 5-year pay-back periods. With solar compared to the average cost of fuels, even the most expensive electric fuel, it is only getting 8-year payouts.

The solar technologies are going to have a hard time. That is why I think you have to take a look at the broader question, which is the question of replacement costs.

The problem is that the signals that we are sending the consumer now are really not signals that are right for society as a whole.

For his own particular individual choice, he is rationally economic to continue to use natural gas particularly, secondly oil, and thirdly electricity, and not to put in any conservation or only minimal, to do maybe a little bit of passive, a little bit of solar water heating.

But if you look at this from an overall societal point of view and the overall dollar flows involved, international balance of payments and the real costs of replacement of electricity and fossil fuels, you find that that is kind of a crazy decision when you add up all those individual microdecisions.

That is really I think the central reason why we really need these tax credits very quickly; secondly, why we need to understand the decision process better, and develop commercialization strategies that deal with the matching of what is a reasonable technology and reasonably close economically into the private marketplace.

Mr. WUNDER. Thank you, Mr. Chairman.

Mr. GORE. Mr. Greene?

Mr. GREENE. Thank you, Mr. Chairman.

Just one final question to follow-up on Mr. Wunder's question.

Recognizing that most of us are fairly conservative when buying a home, should it be part of the criteria in any design competition that they demonstrate or have demonstrated substantial commercial acceptance; that is, for example, in California it will be a ranch-style home that would get extra credit, and perhaps in the northeast it should look a lot like a Cape Cod home which has sold in the past.

Mr. HIRSHBERG. I think that should be one of a number of criteria. I would not have that be the exclusive criteria. But yet, it should be an important factor.

Mr. GREENE. Just briefly, what would be the other criteria which you would include?

Mr. HIRSHBERG. The reason I would not want to make it the exclusive criteria is I think there are other technical reasons for doing demonstrations that don't deal with market potential.

I wouldn't want to say that innovativeness stopped. I think there are also potentially systems that are not in favor now, or designs not in favor now, that could be in 3 to 5 years.

Mr. GREENE. I have no further questions, Mr. Chairman. Thank you.

Mr. GORE. On behalf of the subcommittee, I would like to thank all of the witnesses who have come and testified today. It has been very enlightening. As the chairman said at the outset, this series of hearings will continue, but for the moment, we will stand adjourned.

Thank you.

[Whereupon, at 1:40 p.m., the subcommittee adjourned.]

