CONVERTING SOLAR ENERGY INTO ELECTRICITY: A MAJOR BREAKTHROUGH?

HEARING

BEFORE A

SUBCOMMITTEE OF THE COMMITTEE ON GOVERNMENT OPERATIONS HOUSE OF REPRESENTATIVES

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itself but restoring the United States and other free nations of the world to an independence option which we do not presently have because of our dependence on oil from foreign sources. The implications then for whatever discoveries can be made are extremely significant.

Our first witness this morning is Mr. Joseph C. Yater, who is a physicist from Lincoln, Mass. He has his own consulting firm. He has had a distinguished career in space physics, sensor and data collection systems, thermal design of power systems and statistical mechanics. He has submitted an invention to the Office of Energy-Related Inventions under the National Bureau of Standards.

That office conducted a series of evaluations and just a few days ago recommended this invention for Government support by the Energy Research and Development Administration (ERDA).

We will also hear from both of those agencies this morning.

Mr. Yater, we welcome your appearance before the subcommittee.

We will administer the oath at an appropriate time. It is our custom to do so—and no more than that.

With that, the floor is yours and we would like to hear the details about your idea and its prospects.

STATEMENT OF JOSEPH C. YATER, LINCOLN, MASS.

Mr. YATER. Thank you, Mr. Chairman.

I wish to express my appreciation for the opportunity to give this statement on an invention to convert heat or solar energy directly into a useful form of electric energy.

My statement here today may vary in some ways from my prepared statement and I wish to request permission to also have my prepared statement submitted in the record.

Mr. RYAN. Without objection, your entire prepared statement will be included in the record.

(See p. 13.)

Mr. YATER. In this statement I will first describe the technical features of the invention, and then I will discuss some of the applications of the invention.

For the patent application on this invention, all 31 claims have been accepted and the final granting of the patent is being processed on the high priority basis being granted to some energy-related inventions.

Before discussing the circuit and performance of this invention, it is useful to discuss briefly the general nature of fluctuation voltage, inasmuch as the use of fluctuation voltages is basic to this invention.

As a preliminary comment to this discussion, it is also useful to note that, inasmuch as the discussion of fluctuation voltage depends on thermal motion of electrons, it is necessary to have a heat input source.

This can be any kind of heat source, but the most important source, by far, is solar energy; and for the following discussion it will be assumed that when solar energy is the heat source, a solar radiation-absorbing material is placed in thermal contact with the fluctuation voltage generator.

The device of the invention first converts the thermal energy to electric voltage fluctuations which in turn are relayed across a thermal barrier to small rectifying circuits to produce with high efficiency useful direct current output power.

The same device is also able to pump with high efficiency heat from a low temperature region to a high temperature region. The device of this invention is comprised of a first layer of microcircuit modules in which heated resistors or diodes convert thermal energy into electric voltage fluctuations, a continuous second layer of microcircuit modules in which capacitors electrically couple the voltage fluctuations across a vacuum thermal barrier, and, contiguous to the second layer, a third layer of microcircuit modules in which at least one cooled diode in each module converts the electric voltage fluctuations to direct current electric power.

The physical basis for this invention is the surprising amount of power that is available if the fluctuation energy of heated electrons can be efficiently converted to useful direct current power. This fluctuation energy in its familar form is considered a bad thing, as it is the source of amplifier noise that limits the sensitivity of all electronic amplifiers, including radio and TV receivers.

To understand the nature of this fluctuation energy, the following drawing is useful.

[Witness displays diagram.]

Mr. YATER. This is similar to a model for a solid state diode in which you have electrons separated, as shown in this drawing, by a partition. In a diode, you consider that a potential wall.

The electrons are moving about due to thermal energy and are colliding with the walls and with each other; and with the potential barrier.

Occasionally in their collisions, one of them gains energy to cross the barrier. On the average, this will occur with equal frequency in both directions just as when you are tossing a coin, heads and tails occur with equal frequency.

But at any instant, it can be expected that there will be an unequal number that have crossed in one direction as compared to the opposite direction.

This change in the number of electrons on each side of the partition creates an instantaneous voltage difference across the partition.

This then is an example of fluctuation energy that results from the thermal motion of electrons.

Similar fluctuation energy occurs for resistors as well as other electrical circuit components.

The fluctuation energy that exists at the input of a radio receiver is called "noise power" or "noise voltage." The only way to reduce this noise voltage is to lower the temperature of the component which also lowers the velocity of the electrons so that they don't generate as much fluctuation voltage.

The purpose of this invention is to efficiently convert this fluctuation voltage resulting from the heated electron motion to a useful form of output power. The potential power output from this voltage source has apparently been overlooked as it is an impressive amount if it can be efficiently converted to direct current power.

This large potential power exists because an important and fundamental aspect of the fluctuation energy output of a circuit component is that it is independent of the size and number of electrons in the component.

The same device is also able to pump with high efficiency heat from a low temperature region to a high temperature region. The device of this invention is comprised of a first layer of microcircuit modules in which heated resistors or diodes convert thermal energy into electric voltage fluctuations, a continuous second layer of microcircuit modules in which capacitors electrically couple the voltage fluctuations across a vacuum thermal barrier, and, contiguous to the second layer, a third layer of microcircuit modules in which at least one cooled diode in each module converts the electric voltage fluctuations to direct current electric power.

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This large potential power exists because an important and fundamental aspect of the fluctuation energy output of a circuit component is that it is independent of the size and number of electrons in the component.

This means that by making the component smaller, the power output per unit volume of the component is increased. The available fluctuation energy per component is small, as it is only of the order of a microwatt.

However, there is a large potential power output per unit volume for small components. As an example, if the circuit size is reduced to consist of 1 million free electrons, the total power output from the circuits that could be fabricated from 1 cubic centimenter of the metal would be 1,000 billion watts. One cubic centimeter is a very small volume.

Mr. RYAN. Would you kindly repeat that again?

I am having trouble following some of your scientific words and labels.

Could you please repeat that last point you just made?

Mr. YATER. Yes.

The circuit size of a resistor, for example—if you make a smaller resistor, you have not decreased the fluctuation power that comes from it. You can continue to make it down to almost one electron in size, and you still have that same fluctuation energy that is capable of coming out of the resistor.

This works very well with getting a large power output because, as you make your circuit size smaller you get the same power output from each circuit resistor; so, therefore, you have increased your power per unit volume.

That is a fundamental aspect of fluctuation effects. If you have a large number of molecules, the percentage of fluctuation in pressure on, let's say, a wall will be less than if you had a small volume because there are fewer atoms hitting up against that wall. The same is true with the electron motion.

This example is given to show that material costs can be negligible as the circuit size is reduced. This potential power output requires, of course, a power input such as from solar energy of at least 1,000 billion watts.

We are not talking about generating any power in this system. They have to produce the power from the outside. But the fluctuation energy is the way that it is converted from thermal energy into electric voltage fluctuations.

Of course, this also illustrates the material constraints as being so minimal in this system as compared to any other system you could think of.

To realize this potential also requires the ability to fabricate circuits of these small dimensions. As Professor Feynman, the Nobel laureate in physics, stated in an article aptly titled "There's Plenty of Room at the Bottom," there is no foreseeable limitation in this direction as he foresees the development of precise circuit size of a few atoms in width and with the tolerance on dimension size being that of a single atomic layer.

Also, as we all know from the rapidly expanding field of microelectronics, the manufacturing costs are rapidly decreasing as is currently being demonstrated for the pocket calculators.

The purpose of the invention is to give the design of a circuit that will enable the efficient conversion of the available fluctuation energy to useful output power.

This design is simple as you can see from this drawing.

[Witness displays drawing.]

Mr. YATER. The input fluctuation voltage is rectified by a diode to produce a direct current voltage input to the load. For this circuit the fluctuation voltage generator, which can be a resistor or another diode, is maintained at a higher temperature using input power from solar energy or other sources.

The rectifying diode is maintained at the ambient temperature—room temperature—with a vacuum thermal barrier separating the input power from the rectifying diode.

That is all there is to the circuit.

It is a similar circuit electrically to the battery charger, except in this case the incoming a.c. voltage is generated by the heated resistor or diode. In a sense, all you do with a battery charger is that you have an a.c. voltage in and you turn that into d.c. current by rectifying. This is the essential fact that is going on here.

Also in this circuit the power output of each circuit is added to the power output of the other circuits so that the total power output is the combined output of all the circuits.

As I said earlier, the power output of one circuit is insignificant but combined it is truly impressive.

The thermal circuit is quite different from the battery charger circuit as in this invention a thermal barrier is included to prevent any thermal losses being conducted from the heated noise voltage generator to the cooled rectifying diode.

The barrier consists of having a capacitor plate to couple the electric energy across and having in the barrier a vacuum so that there is no thermal conduction path—only radiation path which shows to be truly negligible in this respect.

Therefore, the invention consists of designing a circuit that will enable the input heat or solar energy to be converted into electric voltage fluctuations and then conducting these fluctuations to a rectifying diode maintained at a lower temperature.

Analysis of the circuit and extensive computations show that the maximum theoretical efficiency allowed by the second law of thermodynamics for the operating temperatures can be achieved if significant thermal losses can be prevented from occurring across the thermal barrier. This is the barrier that is maintained between the condenser plates. This result was shown in a paper published in the Physical Review in October 1974.

Mr. RYAN. May I interrupt for just a moment, please?

One of the facts of life here on Capitol Hill is that, irrespective of any desires we may have about pursuing the important things in life, we are required on occasion to report to the House floor to report the fact that we are present.

We will then recess for 10 minutes.

[Recess taken.]

Mr. RYAN. Mr. Yater, I apologize for the interruption. I hope that you will understand. We should be reasonably uninterrupted for some time to come now.

With that, you may proceed from where you were when we recessed.

Mr. YATER. I believe that I was up to the point of describing the circuit shown in this diagram.

If you understand how this works and then you go through the theoretica[l] analysis of it, then you will see that you can reduce the losses in t[he] ry to where the circuit can operate at the maximum efficiency allowed by the second law of thermodynamics.

The vacuum thermal barrier can prevent those losses provided the spacing support for the vacuum can be at a small fraction of the total area. Analysis of the stresses and thermal environment indicate this can be done, however, the actual fabrication of this thermal barrier represents the big step that will demonstrate the feasibility of the concept.

One method of fabrication that has been designed consists of thin films of dielectric substrate material such as quartz maintained in tension on one or both sides of the thermal barrier.

This design of the film support structure follows the analysis shown in the Applied Optics paper in February 1975, pages 526–530, which I wrote, in which the tension exerted at the perimeter of the film maintains an optically flat surface for the film.

That is to try to keep the flat surface here [witness indicates on diagram] so we can couple the energy across there using the capacitor plates.

The distortions under environmental forces can easily be computed for the film support structure and several alternate designs for the film have been analyzed. The results of the analysis show that thermal conduction losses can be maintained within the limit required for the thermal barrier.

Also, the computations show the design can withstand the thermal bending stress, radiation pressure, and the gravitational forces. The design can accommodate several modifications and one of these is to include an additional spaced film on the outside surface of each film support structure. These additional films could shield the inside films and circuits from the outside environment and atmosphere while maintaining the required thermal steady state values.

The design alternatives that were analyzed do show that whereas the solution to problems posed by thermal conduction losses require careful attention, there are apparently no inherent physical limitations to the concept that will prevent the design of a satisfactory thermal barrier.

The power output potential per unit area of the film or rigid supporting substrate is dependent on how many circuits are placed per unit area.

For circuits spaced 10^{-3} centimeters apart and with an adequate energy input, the power output potential is 10 kilowatts per square meter of film area.

For spacings between 10^{-5} centimeters and 10^{-6} centimeters apart and with an adequate energy input, the power output potential is 1 billion watts per square meter of film or rigid substrate area. This is assuming that you had that much power in there.

In the development of this invention, the first step will be to fabricate and test a model containing the thermal barrier. This will be the decisive and important step required to open the way for parallel development of the device for many applications. If this first step verifies the theory, then rapid and predictable progress can be expected. These parallel developments include applications for

outputs ranging from outputs below the microwatt [illegible] of heat pump capacity for lowering the temperature of the in[illegible] circuit of a low-noise receiver to outputs above the 100-megawatt level for space solar power stations.

These applications include the following:

(1) Earth solar power. By concentrating the solar radiation a high input temperature for the device can be achieved so as to enable efficiencies of 80 percent to 90 percent to be achieved for the power conversion of solar energy. The present maximum achievable efficiency of silicon solar cells is 15 percent.

A design has been made for a thin solar concentrator layer that can effectively increase the temperature of the first layer so as to obtain these efficiencies. Other types of concentrators of the solar energy can be also used including either the MIT mirror concentrator announced last week or the MIT Lincoln Lab grid concentrator announced this spring.

(2) A second application is for steam powerplants. Steam powerplants are limited to 40 percent efficiency for electric power generation using fossil fuels. Using fossil fuels, furnace temperatures of 1,700° can be achieved and this would enable power conversion efficiencies of 80 percent to be achieved using this device.

Mr. RYAN. Are you saying that if you used this along with current powerplant usage that you could double the efficiency of the plant?

Mr. YATER. Yes; I am going to say that in the next sentence.

There are two different aspects. If you just substituted for steam power, you would get 80 percent directly, but let's say that you wanted to try to achieve the efficiency from the present one, then you would do the process called topping and tailing which means that you would try to use the energy at a higher temperature than you can—that is, the efficiency you can get from the higher temperature of the furnace than the steam can accommodate; and take that part of the temperature energy and use that in the conversion. Then the tailing is to take the exhaust, that is, the heat that is coming out and get the energy that can be acquired from that.

This device has that application because it has a wide operating range of temperature. You can, then, do that.

(3) Topping and tailing. The wider temperature operating range of the device for efficient power conversion can enable the device to work off the unusable temperature of the waste heat of many other types of powerplants. The range of efficient operation for this device can be from 350°K to the highest furnace temperature so that either by tailing or topping, the efficiency of the other types of powerplants can be increased. This increase, for example, has the potential of doubling the power output of existing steam powerplants.

(4) Space Solar Power Stations. The high output power per unit weight of the micromodules of this invention can enable a weight reduction—of an order of magnitude or more to be achieved over the weight of a silicon cell solar power station if similar efficiencies were achieved.

In addition, if the potential conversion efficiency of the device of 90 percent for the space environment is achieved, then the weight reduction and/or power output advantage over a space solar power station using silicon cells is further increased by severalfold.

The next application is a little difficult to explain but it is an important one.

(5) *Heat Pump or Refrigerator.* When you run this situation, or operation, backward and instead of having power output, you put power input to the diode and made the diode work in a reverse direction, then it actually transfers heat from the colder side to the hotter side.

The reversible cycle resulting from the minimization of losses enables the same thermal cycle to be used in a heat pump mode and a refrigeration mode in addition to the power conversion mode! This mode is the most difficult mode to explain but it can be utilized by simply increasing the voltage at the output terminal so as to reverse the current through the circuit.

There is, then, an input of power to the circuit at the former output terminal. This, in effect, takes heat away from the cold side and delivers it to the hot side.

An important aspect of this mode that is often overlooked is that for most operating temperature ranges, such as for home heating, much more heat can be delivered to the hot side than can be achieved from the same input power delivered directly to the hot side. That would mean inside the home.

This enables the efficiency of the input power for heating purposes to be increased severalfold.

For home use, this reversible operation can result in large energy savings. The same device can be used to generate power for the home, air-conditioning for the home, and heating for the home. To give an example of this saving, the power in 1 square meter of sunlight can be converted into 1 kilowatt of power output by the device operating in a power conversion for the home.

This output power can be stored and later used to operate the device in a heat pump mode for the home.

Then, if, for example, this heat pump mode is operated with the low temperature reservoir at 32° F, and the high temperature reservoir at 90° F, the heat equivalent of 10 kilowatts of power can be delivered to the high temperature for each 1 kilowatt hour of output power stored from the solar power conversion.

So, you don't have to store as much power if you are going to use it in the heat pump mode as you would to directly heat your house.

Finally, it may be appropriate to mention an application to an area that brings the utilization of fluctuation energy full cycle and for this application the circuit is used in a refrigeration mode to reduce the input noise voltage and increase the sensitivity of radio receivers and amplifiers.

For this application a multistage circuit of micromodules is sufficient to produce the microwatt heat pump capacity required to lower the temperature of the input stage of the receiver to a very low value so as to effect a large decrease in the bad fluctuation energy or noise power existing at the input of the receiver.

In other words, you use the same effect to pump heat out; that is, the undesirable fluctuation energy at the input of the receiver.

For the above applications and others, there can be a parallel development as all applications depend on the same basic circuit.

In considering this invention, it is perhaps useful to attempt to estimate and predict some of the long range applications that will occur if the initial stage in the development is successful.

In approximately 5 to 10 years it could be expected that the mass production could be fully automated using a microfabrication technique, such as X-ray lithography, to reproduce the circuits.

Even at that stage, it can be expected that manufacturing costs will be the dominant cost as the material cost can be made truly negligible. This can easily be seen from the example given in the Physical Review article of October 1974 which shows that a cubic meter of these circuits had the capability of delivering 100 kilowatts to each person in a world population of 10 billion.

Regardless of the material cost per unit volume of the material in the circuits, this result indicates how truly negligible the material cost per kilowatt output of power capability would be.

This is even more evident when it is realized that, if tunnel diodes are used, all the circuit components can be made of relatively inexpensive and locally produced metals and, if supporting films are used, the support structure can also be made of an inexpensive material such as glass or quartz.

On the basis of this assessment, it appears that, provided the first step in the development verifies the theory of the device, it is reasonable to expect that the cost per kilowatt will be far below the $200 level that has been stated to be the level at which solar energy becomes more attractive for most applications than the alternative methods of power generation. The size of this device required to generate 1 kilowatt of solar power is only 1 square meter in area with the thickness given by the thickness of the film or rigid substrate support structure. The material costs will be negligible and it appears reasonable to expect that the cost of manufacturing will continually decrease with time and with the quantity being manufactured.

As an example of an application for which large quantities are required, consider the application of solar power for the home. An MIT study has shown that, if 125 watts of electric power plus approximately 700 watts of thermal heat power into water were made available to a home from solar power, a rooftop solar energy unit costing $5,000 would pay for itself in 5 to 7 years.

It would seem reasonable to expect this performance to be feasible early in the development of this technique as less than 2 square meters of effective circuit area exposed to the direct Sun can achieve this performance even if we assume only a 50 percent efficiency is achieved for the solar power conversion.

If this effective circuit area were increased to 20 square meters or approximately 10 percent of a typical roof area, power output of 10 kilowatts output power could be obtained for a 50-percent circuit efficiency. This output power, if stored, is approximately 40 times the present electric power needs of a typical home or about 13 times the heating energy needs of a home.

The heat energy requirement for a home can be reduced tenfold if the device is also used in the heat pump mode for the operating conditions given in the previous example. For this example, the 10-kilowatt output power represents 130 times the heating energy needs of a typical home. For this almost universal application, it seems reasonable to expect, if the first step in the development verified the

theory, that since the material costs are negligible for the 10-kilowatt device and since the manufacturing cost would continue to decrease with time for the high volume production, that by perhaps 1990 the cost of each unit will be much less than $200.

Trying to look even further down the road, it becomes necessary to speculate and perhaps dream a little, but it does seem worthwhile to hope that the day will sometime come when a lightweight portable inexpensive solar power unit can be available to everyone as this may be the only way the people of the undeveloped regions of the world can lift themselves by their bootstraps.

Then, these people can more efficiently move about to develop their land without awaiting the development of large power stations and expensive distribution systems.

The most hopeful aspect of this dream is that this source of power is effectively limitless and will not create any thermal or atomspheric pollution of our planet.

Thank you, Mr. Chairman.

Mr. RYAN. What you say—as far as I am concerned—is so interesting that one is afraid almost to carry it out because of being accused of dealing in exaggeration and hyperbole.

However, if your comments have substance and weight, this could become a very historic meeting.

Would you stand a moment, please, and raise your right hand while I administer the oath?

We now have enough members to do that.

[The witness was then duly sworn by the chairman.]

Mr. RYAN. Mr. Yater, if this system is proven to be feasible, the results could be classified then as near-term or immediate in their impact within the next 5 to 10 years.

Is that a reasonable statement?

Mr. YATER. I think it is reasonable, Mr. Chairman, because the first step is the crucial step but it does not require much time to do it. If that happens, then the rapid development of it can go forward in a near-term future.

Mr. RYAN. Obviously, the impact, as you indicated toward the end of your statement, on American life and on life in the entire world would be measurably and significantly affected.

This committee is particularly concerned, among other things, about the effect on Federal activities and planning.

Do you think this invention could affect Government planning and decisions in ways which would have major impacts on how our tax dollars are presently being spent?

Mr. YATER. Yes, sir.

Mr. RYAN. Do any examples come to mind immediately that we might consider?

Mr. YATER. All energy decisions, as we presently are operating, have long leadtimes.

It would certainly be true that anything that was going to be injected into the pipeline at this stage, which could actually be supplying energy in, let us say, 10 years, would affect the amount of needs for some other power systems.

The only general answer you can give which is certainly true is that the Sun is an unlimited source, as far as our practical needs

here on Earth are concerned, and, if you can manufacture [illegible] and can make them cost competitive, you would certainly find that this would reduce the need for other sources of energy, unless they be used for special applications or in special conditions.

Mr. RYAN. What impact would this have on present plans for nuclear powerplants for the generation of electricity?

Mr. YATER. I think that falls in the same category as this statement.

Nuclear powerplants are long-range investments and have to be considered a long time ahead. So, you would certainly want to be aware of this technology because I think it represents in a sense an alternate which you would like to explore in order to find out as soon as possible whether it can indeed perform and, if it can, it would seem to me that it would cut back on the need for nuclear powerplants.

Mr. RYAN. Then, it would also have, I would assume, a very significant impact on large public utilities because—am I not correct—each home could become its own private utility or electric utility?

Mr. YATER. That is the example I was giving.

You would generate in your own house all you needed in the way of power. This would apply to heat and electricity.

Mr. RYAN. Let us take another application then such as transportation which is one of the crushing pressures we have today—the transportation system and the use of the gasoline powered automobile.

Does this theory of yours have any application for reasonable size motor vehicles which would be powered by solar energy converted into electricity rather than by the present system?

Mr. YATER. In this case, you would have to consider this as an evolving impact.

What you need is first to consider that a 1-square meter of area only gives out 1 kilowatt which is roughly 1 horsepower.

So, you do not have much power as compared to our present automobile.

On the other hand, battery assisted vehicles are possible.

Mr. RYAN. Through storage.

Mr. YATER. If this system were worked into a universal application for this such as in a city, you would have within the city a possibility of generating enough power from the solar energy so that, instead of filling stations, you would park your car in a parking lot and plug it into the battery or your parking meter or whatever. You would then be able to keep your cars in motion from the electric generated power.

Mr. RYAN. So, there is a possibility then that we could continue to maintain the present system of vehicular traffic in this country, using electrical power, by some specific secondary modification without the accompanying pollution of the internal combustion engine?

Mr. YATER. This is certainly true inasmuch as the solar energy that we have impinging on a city is many times more than we would need. We would just have to efficiently convert that from rooftops to give you the energy needed for this.

Mr. RYAN. I have just one more question.

Aside from your particular invention, do you see any need for this country to make a dedicated and top-priority commitment to solar energy as the primary source?

Mr. YATER. I believe our country should.

The reason I say that is because I believe it needs to be said in the sense that people in general have to be energized sometimes to go into new fields that they have not been working in. Our history in the past has been of a very energy surplus Nation. We have not had the motivation to do this.

If we had a different history, we would have been working on it and we would already have given to it the priority that it needs.

Mr. RYAN. Thank you, Mr. Yater.

Mr. YATER. Thank you.

Mr. FASCELL. Mr. Yater, I gather that you would have to have a device to make use of the fluctuation energy of heated electrons.

Mr. YATER. Yes, sir.

Mr. FASCELL. The power to run that would come from a solar concentrator?

Mr. YATER. Any kind of a thermal motion has to have some heat supplied to have this kind of thermal motion.

Mr. FASCELL. So, the heat would be solar heat applied to create fluctuations on heated electrons. Then, you would convert that into usable d.c. power?

Mr. YATER. Right.

Mr. FASCELL. The unit itself does the rectifying?

Mr. YATER. Yes.

Mr. FASCELL. So, you take the solar power, concentrate it to create the necessary heat?

Mr. YATER. Yes, sir.

Mr. FASCELL. In order to create a flow of heated electrons.

The unit itself rectifies that to a d.c. output. Then, you can plug everything in your house to it?

Mr. YATER. Yes, sir.

Mr. FASCELL. I am ready.

Mr. RYAN. Mr. Preyer?

Mr. PREYER. Your testimony, Mr. Yater, is mind boggling, as the chairman said.

I notice from you résumé that you are currently working under a National Science Foundation grant on a study of power conversion.

Is that this particular project?

Mr. YATER. Yes. It is a 6-month study funded at $9,000.

Mr. PREYER. How much longer does that grant have to run?

Mr. YATER. This month.

Mr. PREYER. I notice that, under patents, you list power conversion of energy fluctuation filed September 1975.

Is that the device here?

Mr. YATER. Yes, sir.

It has been submitted under the priority treatment given to energy-related inventions. It has been handled very rapidly. The claims have already been granted.

Mr. PREYER. You mentioned that your grant from the National Science Foundation expires this month.

Do you need another grant?

Do you need a renewal of that grant to pursue this further?

Has there been an indication as to whether or not you would get a renewal?

Mr. YATER. It would be helpful to get it.

I have not submitted a proposal.

It usually takes about 6 months. Every time you ask for a renewal, you have to submit a new proposal.

So, as I understand it, the earliest I could get an approval would be in December of this year.

The proposal has to go out for review.

Mr. PREYER. Have you submitted that proposal?

Mr. YATER. No, sir.

I was working quite hard to get this material together. I have been doing some computation work on it. I felt that it was premature to submit the proposal before I had gotten the results together.

I intended to do that, barring some other fortunate source of funds that might help it go along.

Mr. PREYER. My final basic question is this.

What needs to be done to test out the idea?

I gather that, right now, it is in the theoretical stage?

Mr. YATER. Yes, sir.

Mr. PREYER. It has not been demonstrated anywhere?

Mr. YATER. I think that there is a common consensus that the next step is to manufacture a limited size module, that is, a limited sized circuit—perhaps 10 centimeters on the side of this micromodule—test it out; check the thermovacuum, that is, the barrier; and then, measure the output power.

From that, you can scale so many things that really that step is the big step.

In other words, once you got that experimental result and it verifies your whole theory, unless there is some unexpected and surprising development, you can go forward very rapidly from that to all the applications.

Mr. PREYER. So, the next step then, in order to advance this idea, is the demonstration?

Mr. YATER. Yes.

Mr. PREYER. I gather that application has been made to ERDA or someone?

Mr. YATER. I believe the next witnesses will talk about this subject and where it goes from here, and what is the situation.

Mr. PREYER. Thank you very much, Mr. Yater.

Mr. RYAN. Thank you, Mr. Yater. We appreciate your being here if for nothing more than because, I hope, you have excited others as much as you have excited me. We are closer to a solution to a very fundamental problem.

[Mr. Yater's prepared statement follows:]

Mr. RYAN. We will now call Mr. George Lewett and Mr. Albert Hedrich.

[The witnesses were duly sworn by the chairman.]

STATEMENT OF GEORGE P. LEWETT, CHIEF, OFFICE OF ENERGY-RELATED INVENTIONS, NATIONAL BUREAU OF STANDARDS, DEPARTMENT OF COMMERCE

Mr. LEWETT. I appreciate this opportunity to appear before you to discuss the National Bureau of Standards' program for evaluation of energy-related inventions.

The Office of Energy-Related Inventions was established in April 1975 to carry out the responsibilities assigned to the National Bureau of Standards under section 14 of the Federal Nonnuclear Energy Research and Development Act of 1974.

Section 14 directs NBS to assist the Energy Research and Development Administration (ERDA) by evaluating promising energy-related inventions. Particular attention is to be paid to those inventions submitted by individual inventors and small companies for the purpose of obtaining direct grants from ERDA.

The principal functions of our office are to determine the potential value of inventions submitted directly or through ERDA to NBS for evaluation, and formulate recommendations for or against ERDA support to develop or otherwise encourage utilization of the inventions.

In our first 13 months of operation, response by the public to the program has been substantial. Total correspondence in and out of the office averaged approximately 50 letters per day for a total of over 14,000 items for correspondence in the past year. The office responded to over 4,000 inquiries by sending out evaluation request forms for inventors to use in submitting inventions. To date, more than 2,200 of these have been returned with invention disclosures attached for evaluation.

In program development over the past year, considerable attention has been given to designing an evaluation process which would meet the needs of individual inventors and the small business community. We have attempted to minimize paperwork: invention disclosures are accepted in the form most convenient for the inventor; there are no rigid format requirements; only one copy of the disclosure has to be submitted.

We have been particularly attentive to the problems of safeguarding the proprietary rights of the inventor; a rigorous security system has been established to restrict and closely control accessibility to disclosures, and to hold Government personnel and contractors formally accountable for each invention disclosure handled.

In designing the program we also had to anticipate that only a very small percentage of the inventions submitted could be expected to have significant value. The prior experience of NBS over many years in reviewing invention disclosures submitted by the general public told us that, as did the experience of other organizations involved in invention evaluation. At the same time, however, we also knew that any one such invention can be extremely valuable, and its identification could make the entire program worthwhile.

In consideration of these factors then, we knew that all submissions could not be treated the same. To the extent possible, expenditures

should be greater on inventions with promise. We would ... looking for "needles in the haystack"; our objective would be to seek out those very few inventions that could be valuable.

If we were to err it should be in the direction of calling a poor invention good, rather than the other way around. In addition, when an invention is identified as valuable, every effort should be directed to moving it through the process as rapidly as possible.

The evaluation process we designed to meet these requirements is now in full operation. The first major step in the process is a nontechnical, noncritical review of the invention disclosure submitted by the inventor. The intent in this review is to make sure that the disclosure is sufficient to insure that the inventor receives appropriate attention and consideration in technical evaluation, and that every submission, regardless of outward appearance, receives a thorough reading and review.

At this step also we screen out those submissions which are outside of program scope, for example, those which are not energy related or are nuclear in nature; perpetual motion machines; irrational or unintelligible disclosures; or suggestions which do not have sufficient technical depth or detail to warrant evaluation.

If the disclosure is found to be suitable for consideration and within program scope, the invention then enters the first stage of evaluation. In this first-stage evaluation, we obtain at least two independent technical opinions from qualified evaluators who are senior engineers or scientists. These evaluators are directed to review the invention disclosure thoroughly in order to provide a recommendation for or against support. The review is limited to developing an understanding of the invention's operation and construction, determining its technical validity, and assessing its potential and realizable energy saving value.

The review does not extend to a detailed analysis of performance or of the inventor's claims. The evaluators are requested to comment briefly to justify their recommendation but to keep written comments to a minimum. This policy of "thorough review but cursory documentation" is dictated by the economics of the evaluation program.

Evaluator recommendations and comments are then reviewed by a senior staff member of OERI, and a decision is made whether to continue to second-stage evaluation. If the decision is not to continue, the inventor is notified that the evaluation is complete and that we do not recommend his invention to ERDA for support.

Second-stage evaluation of the invention entails more extensive and intensive review, data development, and analysis, and yields a formal evaluation report. If the end result is a recommendation to ERDA for support, this report is expected to serve as the principal basis for ERDA decisionmaking on the nature and extent of support to be provided. The inventor is given a copy of the report in any case. The format of the report will vary with the nature of the invention and specific details furnished in the disclosure.

Generally the inventor's claims for performance and effectiveness of his invention will be investigated in depth; technical and commercial feasibility will be examined; and subsequent steps required to be taken for invention development will be discussed. The report makes a technical case for support of the invention so as to minimize further investigative or evaluative effort by ERDA in arriving at its decision.

With transmittal of the evaluation report and a recommendation to ERDA, the NBS role is essentially completed with respect to the recommended invention. However, in view of the need to maintain a feedback of end results for improving the effectiveness of the evaluation program, we have established a policy of monitoring the further efforts of ERDA in supporting or not supporting an invention recommended by us. To that end, the senior staff member, who has been assigned responsibility for second-stage evaluation, is directed to maintain cognizance of the invention and its progress throughout subsequent proceedings.

Mr. Albert Hedrich was assigned as the senior staff member responsible for evaluation of the invention described to you earlier by Mr. Yater. Mr. Hedrich, whose testimony follows, will discuss the specifics of our evaluation of Mr. Yater's invention.

This concludes my presentation. I will be happy to answer any questions you may have.

Thank you.

Mr. RYAN. The initial question I have is this. It relates to inventions initiated in other countries.

Do you have any traffic in inventions submitted from other countries to evaluate here?

Mr. LEWETT. Yes, we do, sir; quite a few, in fact. I would venture to say that, out of the 2,200 we have now, approximately 20 are from other countries.

Mr. RYAN. I will postpone my questions until we have the other comments.

Mr. Hedrich, we will be pleased to have you proceed.

STATEMENT BY ALBERT L. HEDRICH, SENIOR EVALUATOR, OFFICE OF ENERGY-RELATED INVENTIONS, NATIONAL BUREAU OF STANDARDS, DEPARTMENT OF COMMERCE

Mr. HEDRICH. Thank you, Mr. Chairman.

I appreciate this opportunity to comment on the invention submitted by Mr. Joseph Yater for evaluation by the Office of Energy-Related Inventions.

Solar energy represents a source of energy of considerable potential importance. Mr. Yater's invention may assist us to exploit it.

Mr. Yater's invention for the power conversion of energy fluctuations was received in the Office of Energy-Related Inventions on September 18, 1975, and was referred to me for a first-stage evaluation. The material submitted by the inventor consisted of a copy of a patent application and a reprint of a paper published by the inventor in the October 1974 issue of "Physical Review."

I concluded that the concept was theoretically sound but that it would require a substantial amount of development before it could be considered a commercially useful device for the conversion of thermal to electric energy. In particular, I believed that development of an efficient thermal barrier between the hot and cold sides of the device and the very small elements would present difficulties. Since the efficiency of the converter depends directly on both of these factors, they could well represent the difference between success and failure in its development.

I also recognized that, if successful, it had great potential for improving the efficiency with which thermal energy can be converted to electrical energy. An obvious, but by no means the only source of thermal energy, of course, is the Sun.

For an independent evaluation, I referred the invention to a senior member of NBS technical staff, Dr. Chester Page, former chief of the Electricity Division, and now Coordinator for International Standardization Activities. He agreed with me that the concept was theoretically sound but that it should undergo additional evaluation in depth to determine the nature and the level of support to be recommended.

Because of the complexities of this invention, substantially more effort was put into this first stage evaluation than we normally require.

We also consulted on several occasions with the inventor for clarification of particular aspects of his invention. Mr. Yater's cooperation both in first- and second-stage evaluation of his invention has been invaluable. He has invested substantial time and effort to clarify and explain his work.

Subsequently, the Innovation Center at the Massachusetts Institute of Technology (MIT), Cambridge, Mass., was selected to perform a second-stage evaluation.

They concluded that the concept is theoretically plausible but confirmed that the thermal barrier and the very small dimensions of the individual circuits must be studied further to evaluate their effect on the efficiency of the process. They were unanimous, however, in their opinion that the only way in which these factors can be properly evaluated is to build a model of the device.

It should be pointed out that this proposal is based on a theory that has not yet been demonstrated in a practical operating device. Furthermore, there is a risk that it cannot be made to operate efficiently enough to become commercially valuable. However, if it can be developed to operate at an efficiency even close to that claimed by the inventor, it can be extremely important in developing the use of solar energy. The way to determine the true potential of this idea is to build an experimental model and study it.

In our recommendation to the Energy Research and Development Administration we stated that an extended evaluation effort would be necessary to fully establish feasibility of the invention. Until this is done, we will not know how valuable it is.

This invention may represent a very significant advance in the efforts to use solar energy more effectively. It meets, in my judgment, all the criteria for support by ERDA under this program.

Thank you, Mr. Chairman.

I will be happy to try to answer any questions you may have.

Mr. RYAN. Your last sentence is the most impressive of all.

The only comment I can make now, aside from any specific questions, is this. It occurs to me in listening to this testimony that this country and this Congress are committed to literally billions of dollars of research. We are looking for—as already referred to by Mr. Lewett—a "needle in a haystack."

I am aware of the pressure upon you because of the enormous need this whole world has to find—for the first time since the discovery of oil in 1859 in Pennsylvania—an alternative source of energy which the entire world can begin to use.

The man... in which you evaluate and the responsibility which you have to be accurate in rejecting those alternatives which do not have value and encouraging those which do have value is extremely heavy and very high.

I do appreciate your comments about this particular device.

Mr. Hedrich, if the Yater proposal could be realized, what would some of the practical applications be and how long would the next stage of development take?

Mr. HEDRICH. If I may, I would like to answer your last question first.

In my judgment, the next step should probably take 6 months to 1 year. I do not believe that it can be carried out or should be carried out in parallel with any other steps. I think that we have to build a model. We have to demonstrate the theoretical predictions.

After that, then I see a series of parallel efforts to develop the various components. I think that this could be done over a period of several years.

I would hesitate at this point to make a prediction as to just how long it would take to bring this to fruition because there are too many unanswered questions at this point.

I do believe that within 1 year we should know whether or not we should go into an extensive development effort.

Then, if that effort is successful, I see wide applications for this device.

I am quite sure—and I have no hesitancy in saying this—that the applications of this device are beyond anything that has been mentioned this morning.

We are going to come up with applications that we have not thought of yet. I base that on the fact that every development of this nature which I have had anything to do with has always worked out this way.

I am not saying that I think this will work. I don't know. But I do think that it is worth the good old college try to make it work.

Mr. RYAN. Mr. Lewett, do you think that your bureau and ERDA are equipped and funded to go onto the next step? That is, to your satisfaction?

Mr. LEWETT. Of course, I cannot answer for ERDA.

Mr. RYAN. How about your bureau?

Mr. LEWETT. We are not funded to carry out this next phase.

My best estimate is that it would range somewhere in the order of $50,000 to $200,000. My program is not funded to undertake this size evaluation.

Mr. RYAN. We will talk to Dr. Hirsch about that.

Mr. Hedrich, do you believe the technical obstacles which stand in the way of this proposal can be overcome?

Mr. HEDRICH. Yes, I do.

I think they can be overcome.

I would have to add that if I am wrong, it wouldn't be the first time.

Mr. RYAN. If you are wrong, there will be nobody who will criticize.

What we are looking for is the right answer, and we are all trying.

Mr. Preyer?

Mr. PREYER. I gather, Mr. Lewett, that you have reviewed some 2,200 applications so far.

How many reviewers do you have to review those?

Mr. LEWETT. My in-house evaluation staff—and when I say in-house it is the staff of the office—consists of three, one of which is part time.

However, I am privileged to draw on the staff of the rest of the NBS as I did in this case with Dr. Chet Page.

Of course, I do use contractors extensively.

Finally, I am currently actively engaged in extending my in-house evaluation staff.

Mr. PREYER. Do you think this system is working whereby you have an R. & D. responsibility for the Nation's energy in one agency and a review of energy-related inventions in another agency?

Mr. LEWETT. That is a very appropriate way to operate.

One thing that such a system guarantees is a completely objective evaluation without undue consideration for what has already been programed in R. & D.

Mr. PREYER. Where some really promising proposal comes out of the 2,200 that you review, do you have any special procedures for expediting that?

For example, in this particular project, is there any expediting of it that is done?

Mr. LEWETT. The procedure is to assign full responsibility for the invention to a particular member of the office evaluation staff with instructions to expedite it. Such an assignment takes precedence over anything else that that particular staff member handles. For example, Mr. Hedrich has lived with Mr. Yater's invention since he first picked it up in early September. His instructions then were to expedite and move it as rapidly as possible.

In this particular case it was very difficult to move the invention rapidly, inasmuch as it was very early in the program and we had startup procedural problems to contend with.

Mr. PREYER. Thank you very much.

Mr. RYAN. I have one more question, Mr. Lewett, which has to do with administration and the coordination of Government agencies which are constant problems we look at on a regular basis in all of the subcommittees of the Committee on Government Operations

There is an overlap between your function in research and development and the research and development responsibility of ERDA.

Do you think that overlap is effective or inefficient; or what kind of comment do you have?

Mr. LEWETT. It is an overlap that we do have to fully define in discussions between myself and the corresponding sponsoring office in ERDA. It does need definition.

We are proceeding with that definition, and I am sure that we will resolve it.

Whether we will ever resolve it completely to the satisfaction of ourselves and ERDA, is another question.

Mr. RYAN. Can you reassure me there is not much chance that something good will fall between the cracks because you thought they were doing it and they thought you were doing it?

Mr. LEWETT. I can assure you of that because if something does fall between the cracks, then my program has a good chance of being rated as not worthwhile and therefore of being terminated.

Certainly we find ourselves recommending into a vacuum, that is, nothing happening as a result of our recommendations, then I feel that the program would cease to be funded; and I think it is within my responsibility to take every step to make sure that that does not happen.

Mr. RYAN. Thank you.

I hope that you will bear with us. We will have to go over to the House floor for a vote.

[Recess taken.]

Mr. RYAN. The committee will come back to order.

Our next witness is Dr. Robert L. Hirsch.

[The witness, Dr. Robert L. Hirsch, was duly sworn in by the chairman.]

Mr. RYAN. Dr. Hirsch, you may proceed.

STATEMENT OF DR. ROBERT L. HIRSCH, ASSISTANT ADMINISTRATOR FOR SOLAR, GEOTHERMAL, AND ADVANCED ENERGY SYSTEMS, ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Dr. HIRSCH. Mr. Chairman and members of the subcommittee.

I appear before you today to testify on the arrangements ERDA has established with the National Bureau of Standards (NBS), Department of Commerce, for the evaluation of energy-related inventions. At your request I will specifically address an invention on which the Bureau has just recently given ERDA a favorable report.

Before responding to the specific requests contained in your letter to Dr. Seamans dated June 4, 1976, I would first like to review the background of the arrangement between the Bureau of Standards and ERDA and the way it is being administered.

The Federal Nonnuclear Energy Research and Development Act of 1974—Public Law 93-577, December 31, 1974—states in section 14:

> The National Bureau of Standards shall give particular attention to the evaluation of all promising energy-related inventions, particularly those submitted by individual inventors and small companies for the purpose of obtaining direct grants from the Administrator (of ERDA). The National Bureau of Standards is authorized to promulgate regulations in furtherance of this section.

You have already heard this morning from the representatives of the Bureau of Standards as to how it administers this legislation. ERDA, of course, provides funding to the Bureau in support of this activity. The amount was $1.5 million for fiscal year 1976 and the transition quarter. The President's requested budget recommends $1 million for this purpose in fiscal year 1977.

Let me now describe the action taken by ERDA to process proposed inventions which have been evaluated by the National Bureau of Standards and recommended for ERDA support. The NBS recommendations are received by ERDA's Office of Industry, State and Local Relations (ISL) which refers them to one of ERDA's program activities for a 30-day review to determine what action the agency should take.

The program activity is asked to select one of three options, namely:

(1) TO PICK UP THE NBS-RECOMMENDED PROPOSAL FO[illegible]MEDIATE SUPPORT

This option requires normal programmatic and procurement consideration with full recognition of the technical evaluation of the National Bureau of Standards.

(2) TO REJECT THE PROPOSAL, WITH THE RECOMMENDATION THAT ERDA NOT BECOME INVOLVED IN ANY WAY WITH THE PROJECT

This option provides for the introduction of considerations such as programmatic desirability, economics, environmental considerations, and prior dealings with the inventor or with similar devices that may not have been considered in the Bureau's evaluation.

(3) TO REFER THE PROPOSAL BACK TO THE OFFICE OF INDUSTRY, STATE, AND LOCAL RELATIONS FOR A MARKET TEST—AN EFFORT TO DETERMINE WHETHER THE PROPOSAL IS SUPPORTABLE IN THE PRIVATE SECTOR.

This option can involve a small grant to the inventor to cover expenses associated with preparation for visits and travel to sources of private capital to seek support for the development, or to seek licensing arrangements where appropriate.

In exchange for this support, ERDA receives access to the evaluation of these outside parties. When the invention or idea is not picked up by the private sector, this information is available for subsequent review by ERDA.

The intent of following this option is to establish inventions in the private sector wherever possible or to accumulate additional evaluation indicating why private support is not available.

Thus far, four favorable recommendations have been received by ERDA from the National Bureau of Standards under these arrangements. The first two were referred to the Assistant Administrator for Conservation, who exercised option 3 and returned them to ISL. The third was received just last week and has been referred to the Assistant Administrator for Fossil Energy.

I am submitting for the record a brief summary of these cases.

The fourth recommendation is the proposal by Mr. Joseph C. Yater, of Lincoln, Mass., which has just been referred to the Office of the Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems.

Mr. RYAN. Without objection, the summary of the cases you mention will be included in the record at this point.

[The information follows:]

INVENTIONS RECOMMENDED FOR ERDA CONSIDERATION BY THE OFFICE OF ENERGY-RELATED INVENTIONS, NATIONAL BUREAU OF STANDARDS

1. Stephen Feldman, Environmetrics, Inc., Worcester, Mass., *Demand Metering System for Electric Energy.*

Summary.—This invention provides a technique whereby a consumer's electric meter can be adjusted by the utility company to run at any one of several rates, depending on the load on the utility at that particular time. The meter would run faster at high loads thereby increasing the cost of power used by the consumer at times when there is a stress on the utility. The rate at which the meter operates would be adjusted by means of signals transmitted over the power lines from the

utility control center. In addition, an indication would be given to the consumer of the rate at which the meter is running at any given time, probably by an indicator panel installed in the residence.

Recommendation by NBS.—Recommended as technically valid and worthy of consideration by ERDA for support. November 26, 1975.

ERDA response: Reviewed by Office of the Assistant Administrator for Conservation. Referred back to ISL April 21, 1976. Mr. Feldman is planning to submit an informal letter proposal outlining the expanded program for development of his meter. ERDA will then review the proposal and if it does not pick up the funding, will assist the inventor in obtaining private sector development funds.

2. Rita Frank and Lawrence Kleinbert, Flair Manufacturing Corp., Hauppauge, New York, *Fuel Miser.*

Summary.—This device is an attachment that can be used to retrofit a room thermostat with a synchronous motor-driven clock timer and an auxiliary heating element to enable it to have a temperature set back cycle. The device, which can be installed with a screw driver, sets back temperature controls once every 24 hours by external application of heat to the thermostat. Both winter heating and summer air conditioning modes of operation are provided for.

Recommendation by NBS.—Recommended as technically valid and worthy of consideration by ERDA for support. November 28, 1975.

ERDA response.—Reviewed by Office of the Assistant Administrator for Conservation. Referred back to Office of Industry, State and Local Relations (ISL) April 2, 1976. A brochure is now being written with ERDA support to promote the concept of "automatic night setback."

3. Donald C. Erickson, Energy Concepts Co., Annapolis, Maryland, *Hydrogen Generation from Producer Gas by Oxidation-Reduction of Tin.*

Summary.—This system presents a new approach to the generation of tonnage amounts of hydrogen from carbonaceous fuels, using tin reduction. The process consists of two reactions: steam with tin, whereby hydrogen is produced, and the reduction of the tin oxide produced in the first reaction by a reducing gas back to tin, which is recycled. The advantages of this process relative to existing hydrogen generation processes are that:

Any carbonaceous fuel can be used to produce the reducing gas, including coal and synthoil;

Pure hydrogen can be produced using a reducing gas which is generated using air rather than pure oxygen;

Gas purifying components such as carbon dioxide scrubbers and shift converters are not required;

A reforming furnace is not required.

Recommendation by NBS.—Recommended as technically valid and worthy of consideration by ERDA for support. May 21, 1976.

ERDA response.—Referred to the Office of the Assistant Administrator for Fossil Energy.

4. Joseph C. Yater, Lincoln, Massachusetts, *Power Conversion of Energy Fluctuations.*

Summary.—This device is claimed to be able to convert thermal energy into usable electrical power with high efficiency. The basic concept is that the thermal shot noise generated in an electrical circuit can be rectified and used for power by cascading large numbers of such circuits.

Any resistive element exhibits a randomly varying voltage across it. As its temperature is increased, the magnitude of the voltage increases. If this current could be rectified, the resultant current would represent a useful available power. Thermal energy could be provided from any of a variety of sources. For such rectification to take place, a rectifying diode must be maintained at a temperature lower than that of the hot resistor. The greater the temperature differential the greater the efficiency of the conversion to electric energy. This consideration leads to the requirement for an efficient thermal barrier between the two elements. A major goal of the research effort would be to evaluate the available techniques for obtaining such a thermal barrier. A second major goal would be to evaluate the capability to produce circuits of the very small dimensions required using state-of-the-art techniques.

Recommendation by NBS.—"We recommend this device . . . as an invention which is worthy of consideration for appropriate Government support. Initial support . . . should be directed to fully establish technical validity." June 4, 1976.

Response by ERDA.—Referred to the Office of the Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems.

Dr. Hirsch. Now let me turn to the organization and arrangements within the Office of the Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems (ASGA).

Any energy-related invention referred to my office with a favorable recommendation by the Bureau is promptly and fully considered by the Division of Solar Energy, the Division of Geothermal Energy, or the Division of Magnetic Fusion Energy in the cases where the invention relates to the energy systems these divisions are developing.

Other inventions and associated grants for research are referred to Dr. James S. Kane, Deputy Assistant Administrator for Physical Research.

Recently we informally established a special unit under Dr. Kane to support novel and revolutionary energy concepts that do not have an obvious home elsewhere in the agency. These ideas can come from any source inside or outside of the Government.

Now that I have reviewed the ERDA procedures and background, let me turn to the proposal by Mr. Yater—power conversion of energy fluctuations.

On June 4, 1976, we received a letter from the Bureau of Standards stating that Mr. Yater's concept is theoretically sound. The reviewer commented, however, that several potential difficulties must be evaluated, namely:

(1) The achievement and maintenance of a thermal barrier of very small dimensions;

(2) The fabrication of extremely small and densely packed circuit elements; and

(3) The identification of materials that will perform satisfactorily at the high temperatures required for acceptable efficiencies.

The second stage of the Bureau's evaluation, performed by the Massachusetts Institute of Technology, recommends that additional research be conducted and that a working model be constructed. This would furnish the additional information necessary to evaluate more fully the potential of this invention and determine its utility as a product.

I have requested Dr. Kane to review these recommendations and to report to me within 30 days as to what actions should be taken. We will be pleased to inform this subcommittee of the outcome of this review.

Let me now give you a few direct comments.

I am by background an engineer and a physicist. Ideas like this come along periodically. They cause the Adrenalin to flow.

Here is a novel and clever and new idea. It is exciting to have such things come to us. It is exciting to begin to do the research and development necessary to determine what something like this can do.

Oftentimes what we find is that something doesn't work very well at all.

Other times, we find that the directions we start in with a new idea of this type get modified, and oftentimes other things come out of it.

But these are the kinds of things which are exciting and are fun. So, I am very enthused about what we have here.

I can guarantee you personally that ERDA will follow up vigorously on this. I have a personal interest in this, as does Dr. Kane; and you can rest assured that this will not fall between the cracks.

There is significant potential here, but we don't know what that potential really is.

Mr. Yater gave you a rundown of some of the things that could happen if this thing is developed to the limit that the theory indicates might be possible.

The thing that we don't know today is what are the practical limits of a device like this. There are significant technical problems. There are also significant technical opportunities here.

In energy, the bottom line—almost always, and I know of no case where it is not—is cost. The thing we can't say today is what would be the cost of an energy conversion system like this.

It looks as though it could be attractive, but we will not know until we get further into the problem.

We have to do the research and development and demonstration.

To give you some idea of one of the inherent characteristics of this particular device, let me say this. It comes in very small sizes, and that can be attractive. There is the potential for microcircuit techniques, which have come very far.

On the other hand, the output of a single unit cell of this type would be of the order of one-millionth of a watt—one one-millionth of a watt.

So, to power one 100-watt lightbulb would require 100 million of these devices. So you see that we have a long way to go to be able to produce these units in a quantity and at a cost whereby they could be economical.

This doesn't deter us because we have a fundamentally interesting idea here. So we will be getting at it. But I think that one has to keep it in perspective.

I, like many other people, am looking for solutions to the energy problem—not a solution, but solutions.

In ERDA—and I am not giving the party line but my own personal views here—we have a good approach. It is a multipronged approach to solve the problem. We hope that we will come up with solutions that have low cost and that are environmentally more attractive than the things we have today.

I think it is quite obvious that we have an interesting idea here, but let's wait a little while to get a better understanding before we begin to alter the course of the activities that are already underway.

Thank you very much.

Mr. RYAN. Can you give me some estimate regarding the time involved that will give us some conclusive comment on the applicability, both in a technical sense and in an industrial or production sense, regarding this particular item?

Dr. HAUSEN. The situation is this:

What one must do first is to demonstrate technical feasibility. I am somewhat familiar with what is involved in this particular invention. I was an experimentalist myself in the past.

I think there is a very high probability that a demonstration can be built that will work. I don't think that will be the major problem.

I think that, depending upon Mr. Yater and on the availability of money on our side—which I think in the kind of time scale we are talking about is not going to be a limiting factor—we have to come up

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with an institution to work with Mr. Yater on this sort of thing. We have to write a contract.

I think that we can get started relatively quickly. I think that the estimates given you before are probably pretty good.

In other words, to have a working model within 6 to 12 months is probably a good estimate.

Beyond that, the hard part then comes. It is part of doing the kind of research and development necessary to come up with optimum components—optimum thin films as Mr. Yater indicated and optimum sealing techniques and optimum techniques to produce the diodes and things of that sort.

Then, of course, this has to be done in an integrated whole.

Then, we have to begin to look at how one could produce these devices. If one needs 100 million to power one 100-watt lightbulb, then one can't just do that in the laboratory by one person making individual units.

So, just to test a significant wattage level will require setting up a significant assembly line for this sort of thing.

That is going to take, I think, a number of years.

Mr. RYAN. It seems to me, from what has been said so far this morning, there are two kinds of energy inventions or research and development kinds of elements to deal with.

One is the kind where you make the present systems more productive, more useful, more effective, and more efficient. The thermostat works better at home, and so does the kind of windowpane which keeps the heat inside the house and the kind of insulation material for the roof.

This essentially continues the present system, only it does so in a more efficient way.

Then, there is the other kind where there is a possibility—if it is feasible—you are off in a whole different direction.

When you talk about those kinds of developments, you talk about some pretty massive potential changes.

For instance, every public and private utility in this country would be greatly affected by Mr. Yater's invention if it turns out to be successful.

I am talking about billions of dollars of capital investments, directly and indirectly in a secondary sense.

When you talk about any development like that, I am of a suspicious enough nature to believe that there are elements which would rather not see Mr. Yater's invention become too successful.

This leads to my next question.

Do you believe or feel there are outside pressures placed upon you and your agency in regard to this kind of discovery which you would characterize as unhealthy or uncomfortable?

Dr. HIRSCH. Absolutely not.

I guarantee, sir, that, if I were put into a position where my judgment indicated that we needed to go in one direction and there were pressures to push in another direction for arbitrary reasons—political reasons—you would see my resignation and a statement as to why I resign.

Mr. RYAN. I hope you would send a copy of that letter to this subcommittee.

Dr. HIRSCH. I will tell you——

Mr. Ryan. . . can tell you there would be more than a single resignation involved.

Dr. Hirsch. The thing I can say with a great deal of pleasure—because I love this country as all of us do, I think, and the Government gets criticized a great deal, and there are all kinds of conspiracies running around—is that, when dealing with the people I have been dealing with in the Energy Research and Development Administration, I can say that if things get done, not necessarily in the best way, it is because of the mental capacities and the mental limitations of well-meaning people who are well motivated. It is not because of pressures from the outside that they are forced into one direction or another.

Mr. Ryan. Can you make one comment?

My whole line of questions, I think, has to do with what is being done from your own information and knowledge apart from Federal Government research and development.

What has been done by some of the larger power interests in this country along the same line? Is there any significant amount of investment in this kind of thing?

Dr. Hirsch. Years ago the utilities were very conservative and were used to doing business in a very limited manner.

Then, things began to change. The utilities were slow to change. However, as a matter of fact today I think that there is a significant change that has taken place and is continuing to take place in the utility industry.

There is an Electric Power Research Institute, which is significant in size and scope. It is the utilities' research arm. We are working very closely with a number of very competent people there.

In addition to the money the utilities put into that work, they are also individually supporting research and development activities. They are really in the process of coming out of their shells. Some are well out of their shells at this point. Others are coming out more slowly.

However, the movement is very clearly there. They are moving in a much broader direction. They are looking beyond their parochial interests. They really are poking into a lot of corners and markets, which, as a matter of fact, could mean less of a responsibility for them in the future.

Mr. Ryan. Have you received any inquiries from private industry regarding any of the work you are doing so far, such as Mr. Yater's suggestion?

Dr. Hirsch. Mr. Yater's suggestion, of course, is very fresh. As I said, we just learned about it formally this week. We knew that this was coming, however.

Industry is heavily involved in our research and development program in my area—solar, geothermal, and fusion programs.

Industry is very interested in becoming involved in the development of new energy sources. I am talking about not only the small new R. & D. companies, I am talking about the older manufacturers and I am talking also about the utility industry.

Mr. Ryan. One of the strong objections I have, Dr. Hirsch, to the present policy of the Congress and of ERDA itself is the proportion of funds which are available in ERDA to the various kinds of

power development: there is an enormously distorted amount going to—as I see it and it is a very subjective comment of my own—nuclear power in comparison to solar energy in particular.

Could you comment on that and on the validity of my own conclusion?

What do you think we might do here, congressionally, to change the balance?

Dr. HIRSCH. I think we are in part victims of history in the sense that nuclear power was very popular in the postwar period. The Atomic Energy Commission was set up to pursue this very interesting technology. The country did not feel that it had an energy problem for a long time. The result is that we have a very unbalanced energy research and development program—unbalanced from our perspective today.

At the time, of course, there was no concern that we were unbalanced.

We now have a better handle, although not a good handle, on the seriousness of the energy problem—the energy crisis. The result is that we are going forward with a comprehensive program.

That involves moving with a program like solar energy, which around 1970 was funded by the Federal Government at a level of about $200,000. We scaled it up so that this year it is funded at about $115 million. The dollar levels for next year vary anywhere from $160 million to a wild number of $343 million, which I think is too much.

The point here is that, with respect to solar energy, we are correcting the errors of the past. We are beginning to bring these things into a better perspective.

I personally was in charge of the fusion program, prior to assuming my job earlier this year as Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems. A problem I had to face was that fusion was looked on as a backroom research program. The nuclear program was the big program.

So, I had a tough time personally to convince people that they ought to scale up the fusion program. We have been successful in that. The result is that we have a fusion program today that is in better balance overall.

I think that geothermal is another program that has been neglected before. I have responsibility for it now. It is being scaled up and it is approaching, I think, the kind of balance we are aiming for—the kind of balance we want to have.

So, we have a startup problem and we are in the midst of it right now. However, I think we are making good progress. We are aiming toward the kind of balance where intelligent men will differ. So, there you are probably in the right range.

However, we are not there yet.

Mr. RYAN. We could go on further. However, I think the purpose of this hearing this morning has been served.

I believe this subcommittee ought to be pursuing solar energy and other related matters with much more—if you will foregive me the pun—energy than in the past.

I hope to be able to do that from now on. I want anyone, who is here and who is interested, to know that this subcommittee will watch with great interest the progress of Mr. Yater's idea, with the

hope—not with an impractical or beyond reason type of hope, but a rational hope—that this could become one of the most important developments in the latter half of the 20th century.

I think your agency, Dr. Hirsch, and its work is engaged in the kind of effort which I hope will produce that kind of result, either here or in some other area.

This committee's work will go on, as I say, and we will hold hearings from time to time on the subject. Your participation is invited and encouraged.

With that, I think we will adjourn the hearing.

[Whereupon, at 12:15 p.m., the subcommittee adjourned, to reconvene subject to the call of the Chair.]

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