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PROSPECTS FOR CONVERSION OF SOLAR ENERGY INTO ELECTRICAL POWER

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In 1972, the Solar Energy Panel took a broad look at solar energy across the whole field to see just what could be done with this energy source. Maybe the era of acquiring energy without regard to cost and without regard to consequences of using it is beginning to come to a close and maybe we ought to start looking at the newer sources of energy, even though we need every bit of energy we can get from every source. I am not trying to say we don't need gas, oil, coal and nuclear energy. We are not going to use solar energy at the North Pole in the middle of winter and we are probably not going to use fossil fuel energy in places where we can get a reasonable return on solar energy.

The Solar Energy Panel labored hard and really got this field in good perspective and I would like very much to show you what we came up with in that labor. First of all, we identify three areas where we thought that solar energy could have a major impact on future needs. First, thermal energy for buildings, that is the heating and cooling of hot water associated with dwellings, as well as commercial buildings. Due to the fact that there has been a great deal of work done in laboratories at most universities, we felt that this could be brought into commercial readiness (commercial readiness means that we could begin mass producing commercial heating units within five years). Clearly, it appears to be still further away and will take some more development to bring it about, so we estimate by the latter part of the 1970's we will have good systems that will combine both heating and cooling.

Another area that looked very attractive was the production of renewable clean fuels, such as gas. Kansas City, I understand, derives a good deal of their energy from just this very same. We can get hydrocarbons and we can get solid fuels and carbon fuel by charr, that results when we go to a destructive distillation process, and your paralysis process results in the production of oil from organic materials.

Now, if the farmers can take up 15% of our land to make our food, which is 1% of our energy, why can't we devote a couple percent of our land for making energy or making fuel? And we feel that this can be done--the big thing is ENGINEERING--how do you harvest the crops and provide this fuel at the right time and right places in order to produce your energy? Our estimates were that in about 5 to 8 years some of these processes would, indeed, come about and very happily we are seeing some of the cities starting to begin to recycle some of their garbage and that is a big step in the right direction.

For the third area we felt that solar energy could have some impact in the electric power generation area; by concentrating the energy to get high temperatures, which in turn boils water to produce steam, or through solar cells such as those used in the space program since 1958, which can convert sunlight directly to electricity. Wind energy is another one, as well as ocean ΔT which has to do with the production of electrical power when energy is derived from regions where you have the warm overcurrent or very cold undercurrent. On these I envision that it is going to take some development and maybe even a little research to get the costs down to where we can really look good in various areas.

Let's take a look at the availability of solar energy and this has to do with the electric power we think we are going to be consuming in the United States over the next fifty years, from about 1970 up to 2020. In 1970, we consumed something like 14 x 10^{15}BTU's just to generate our electricity. If our projections are any where near accurate, we see that this is going to increase. Let's pick on the current century somewhere around 76 x 10^{15} BTU's will be used to generate the electricity we'll use in the United States by the turn of the century. Now, why if we are not going to have that many more people, is that going to happen? Well, we seem to be going more and more electrical - we like the convenience of it even though it is quite wasteful and it appears that today we are using somwhere around 25% of our total energy to make electricity and by the turn of the century the numbers that we have is somewhere around 45%. It does appear that we are going to be using more and more of our total energy resources for producing electrical power and how in the world are we going to get it? Well, we are going to get it from gas and oil and some of these are going to become synthetic gas and oil, manufactured from coal or shale or tar sands, and we are going to find a good deal more of the natural material in the ground.

Solar energy arrives in the United States at the average rate of about 1500 BTU's per square feet per day; if we could convert that at 10% efficiency, we need about 1 1/2 to 1 3/4 percent of the United States to generate the equivalent of all the energy we need to produce our electric power. Well, if we look at the production of electricity from solar energy by the various processes that are available to us, we come up with some very interesting things. First off, we can have what we call 'kind of a natural collection of solar energy' - that would be by wind power. We estimated that somewhere around 50 megawatts per sq. mile could be generated from wind energy. Now, there are about five regions in the United States where the wind blows steadily enough and high enough velocity where wind power could be attracted. Along the Eastern seaboard, particularly in New England, through the prairie here and the Great Plains of the United States, around the Great Lakes, of course, down the Rockies, along the Cascades along the West Coast and on the Aleutian Islands there is a great deal of wind.

Another renewable energy source has to do with the particular case of growing fuel and burning the wood. We get somewhere around 2 to 3 megawatts per square mile because photosynthesis is not a very efficient process, as a matter of fact, somewhere around 1%, although some of the agricultural people associated with the panel thought that this could be increased, perhaps to 2-3%, making it far more attractive. Ocean temperature differences again is the use of warm overcurrent with some very low, or cold, undercurrents and using a heat engine to extract that energy, operating a Turbine for generating electric power, and there is a lot of energy - 400 megawatts per square mile. Then if we go to a more technological type of collection scheme, we come into thermo energy where we are using concentrators and the thing here is that you must use these in regions where you get a high percentage of direct sunlight. So in regions where it is suitable, say in the southwestern United States, assuming about a 20% efficiency system, you can get something on the order of 100 megawatts per square mile, so you need about 10 square miles for a thousand megawatt power generating plant.

George Sagel made a study on the production of wood to operate a power plant that he defines is a thousand megawatt steam power plant - with 35% efficiency and 75% load factor. He says solar energy is converted by plants somewhere between 24 and 1%. Again, plantologists say it is an insult if you can't grow stuff with 1% efficiency on the land. In a typical growth region we see that we need somewhere on the order of 400 sq. miles to provide fuel on a continuous basis - night and day - 365 days per year, to keep that plant on the line. What this amounts to us is that after a 20 mile by 20 mile sector is planted in trees, they will then begin to harvest regions of this plot until you finally wind up making a complete cycle in a period of about 8 years. This will provide sufficient width to operate the power plant.

We found that in the four corners area they are able to collect solar energy and convert it at 10% efficiency we'll actually have more energy produced from the sun that comes in there every year than all the energy they got from coal they have dug out of there so far. The fact that they only receive the energy from the coal once but the energy from the sun is there every year is the important item. Let's take a look at the four corners region, where we might use solar concentrators and where we have a possibility of collecting the solar energy at high intensity. This energy is piped to the power plant and water is used to generate steam in a conventional way. The big problem here is that you have got to have a region where there is a good deal of sunshine. But, if such systems can be made economically, we can generate some large amounts of power, particularly in the southern part of the United States.

We have, as I mentioned, done some work on solar cells for a good many years in space problems. We are actually finding now that there are many ground applications for solar cells, particularly in unattended and remote locations; where we want to operate navigation aids, warning signals, remote communication systems. We are actually beginning to find that these systems are very competitive; actually less expensive to put on the line and to maintain than the conventional butane-propane burner-type systems that have been used for many years, particularly in navigation of the ocean. Right now , the cost of these things are on the order of about $50 a watt. They can envision that if there is a large enough business, just making them the way we are now, that these costs can actually be brought down to somewhere near $20 a watt. If we can get some automation, we can envision that it will get to $10 a watt and then to get down to $1 per watt is going to be one of the major developments that will have to take place. That is why we are putting 10 to 15 years as the time element required in order to get these costs competitive to another method. You probably are familiar with the Delaware House - it is an experiment to show that we may be able to get a reasonable amount of our electric power for the house from a collector. Now this collector is designed to intercept the solar energy, to generate electric power, the thermal energy to heat is absorbed and is picked up by the air and stored in the basement. They are getting now some of their heating, cooling, hot water and electric power to operate the house. They hope to get about 70% of the total energy of that house derived from the collectors, both the thermal for heating and cooling as well as the electricity.

What sort of thing has to be done before we are going to break that $10 per watt proposition and get down to something under $1 per watt? Necessary for making this panel that costs something under $1 per square, is the solar technology that has got to be brought to bear before we are going to see the widespread application of solar cells on the ground. It seems to me that these proximities can be automated and put to the point where the labor costs are very minimal and amterials themselves can be very simple and very much available, and we can get low-cost solar rays which can be used in many, many applications throughout the country. Not too long ago, about three years ago, we were up against the problem of trying to get high quality reflective coatings on the glass for buildings. One of the organizations that was heavily involved in making coatings for spacecraft solar rays, found that they could build a machine that was capable of taking sheets of glass 2x4 feet and automatically introducing these into the vacuum, putting on the deposit and collecting these at the end of the machine with about three people operating the whole process. The costs on coatings dropped 2 orders of magnitude when they got this machine in operation. Just to show you what can be done when you get away from batch and hand operations rather remarkable things can take place. I guess that this is what is going to happen in the solar arrays. To lay a wquare mile of array which would give us then 10 megawatts of electric-generated capacity--this is the thing that I have been saying is some years off before we are really going to see that. We might take another step and go up above the weather and see what we can do at that point. I had an opportunity to take a look at the possibility of floating a mattress above the weather, just to see what I could come up with. First, I wanted to know where the jet streams were, cause that is a nice thing to stay out of. If you can get up somewhere around 1700 feet, or more, you can get pretty well out of the atmospheric disturbances, get over the thunderstorms, get out of the main jet streams and you can maintain a system at that point. This is only a tenth of the atmosphere. If you can build a structure which is about a hundred feet thick and a mile square, you would have a generating capacity of 250,000 kilowatts. A quarter of a million kilowatts of generated capacity. Of course, you would have this thing with the sun shining on it, you'd want to collect your energy in different places, and then you've got to somehow get that power from the mattress back down to the ground. There are a couple of things you might do, you might put it on a teather, or you could microwave this energy to the ground.

I guess you've all seen a photograph of our sky lab, which was a very successful operation. They managed to rip off one panel during launch and in spite of that, the mission was a tremendous success and did manage to provide those people with the electric power that they needed during the year. Peter Glenjours talks of a satellite solar power station. You plant this at a synchronous altitude and at that point you have mostly sunlight hours, as a matter of fact, you only have a 70 minute maximum interruption during equinoxes about 42 days one side and 42 days on the other side, in the spring and fall. This otherwise is totally in the sunlight. He has looked at the possibility of something under the order of 50 square kilometers, 25 square kilometers in each collector, bringing the power to a transmitter which converst dc into microwaves at about 3 megahertz. Beam this to the ground, where, of course, it is reconverted back to usable electric power. There are at least four major problems associated with this, we aren't even talking about money right now, but let's talk about the four major technical problems associate with the idea. First of all, there is the problem of geeting very low cost solar arrays. These things actually have to come to something of the order of 10¢ to 20¢ a peak watt, in order to come anywhere close to being economic for such a system. The other thing is, getting this into space. This weighs about 50,000,000 pounds, a station of that magnitude would require, with the rockets being developed today, about 3,000 launches. In other words, we have to have a better system developed for getting materials into space. Anther thing, of course, is deploying, orienting, station keeping and attitude controlling all the system. This is several million times larger than skylab which, of course, is the largest thing we have put up so far. The problems associated with that are enormous, but NASA is always willing to face a challenge and this would be a great challenge. The last area, the fourth area, that needs to have considerable investigation and development done, is conversion to microwaves and beaming these back to the ground. There are a lot of arguments as to whether or not this would cause some sort of a physical problem with people getting bathed in microwaves. The answer is 'no', we aren't talking about an intensity anywhere near that. The density is something around 20 milliwatts per square centimeter. Sunlight comes to the earth's surface on a very bright day somewhere around 100 milliwatts per square centimeter. We just aren't going to have any ill affects from that sort of thing. We are always worried, of course about costs. On this I divided it into two parts; the real world and the imaginary world. We don't have any doubts at all that installation costs, at least in 1972, for gas, oil, coal, nuclear, that is, light water reactor plants, were in a range somewhere from $250 all the way up to pushing $500 per kilowatt capacity reactors for installed fuel for nuclear plants. The people working on fast breeder reactors really don't know what those costs are going to be, some are as low as $500 and some are even over $1000 installed kilowatt. As you get into solar thermal systems, there is a very wide estimate here as to those costs ranging from the super optimist of $300 an installed kilowatt to over $2000 an installed kilowatt. It's probable, if you have to make an educated guess, it is more like $1000 an installed kilowatt. If you wanted to build space systems right now, it would cost $200,000 a kilowatt, you're not going to have many stations that cost like that. They've got to come down in cost before we can really talk about competition. The Ocean ΔT System is in need of engineering, of course, ship building and heat exchangers, and we know quite a bit about ship building and heat exchangers, the question is, can you build them big enough, can they work efficiently enough in that system? Those costs look like they might be very competitive with conventional systems, as we know it today.

Wind generators look like they could be very competitive in the systems coming down the line, and we feel that in the woodburning, the only new thing here is how to construct a large plant and get it ready for combustion. The power plant is going to be just like any conventional steam power plant, just a matter of burning the different kind of fuel.

We are always interested in what is happening on the finances; there was very little money that actually went into solar energy in 1971. Something on the order of $90,000 for terrestrial I'm talking about not space. In 1972, somewhere around a million, 1973-2.6 million, 1974-6.5 million went into this whole thing and then in 1975, a couple of weeks ago, it was 17.3 million. This is a very hot topic now and we are not putting enough money into solar energy development. It turns out that instead of the recommendation made by the AEC for 32.5 million, the Office of Management and Budget said that figure should be nearer 50 million. So the field is beginning to increase, we are beginning to see more dollars coming into it. I'm sure that we are going to get many new and good ideas are going to start to break this field wide open where we are going to have a chance for solar energy to become more prominant and, here comes another one, find it's place in the sun.