A PROPOSED NATIONAL WIND POWER R&D PROGRAM

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My interest in wind power began back in 1970 when a group at the University of Massachusetts was studying a proposed increase in the electrical generation system for the Connecticut River Valley. In other parts of New England others were concerned about the problem of how to meet the increasing energy demand without causing serious ecological damage to the New England environment. These studies led to a University of Massachusetts proposal to investigate a national network of pollution-free energy resources - the wind being one of them.

As a member on the NSF/NASA Solar Energy Panel, my involvement with wind power increased. It was clear that a comparison of the energy potential of the different methods was needed. So, I decided to evaluate the potential of wind power using one totally wind-driven system. The objective was to calculate the cost of energy delivered to the customer on demand in New England and to compare this with the cost of energy from systems that were being planned at the time. Meanwhile, the cost of electricity was increasing from 28.2 mils per kilowatt-hour in 1968 to 32 mils per kilowatt-hour.

The system I chose to analyze was the "off-shore wind-power system," which consisted of wind-driven electrical dc generators mounted on floating towers in the waters off the coast of New England where the winds are high. The output from the generators supplied underwater electrolyzer stations in which water was converted to hydrogen and oxygen. The hydrogen would be piped to shore where it would be converted to electricity in fuel cell stations.

With this system, it was estimated that 159×10^9 kilowatt-hours per year could be produced at an average annual revenue somewhat higher than the 28.2 mils per kilowatt-hour of 1968. Even though the estimated price was higher, the absence of the pollution that would result from fusion-combustion processes was a benefit that was worth the added cost. This fact - the reduced pollution resulting from wind power - and some deeper thinking led me to the conclusion that solar energy (includes wind energy) is the only way out of the nation's energy (and pollution) dilemma in the not too distant future. The sooner the nation starts using solar and wind energy, the better off everyone will be. There are several reasons for this:

(1) We have been converting matter into heat at an ever increasing

rate and we may be close to the time when the temperature of the earth is going to start increasing.

(2) The coal, gas, and oil that are left stored in the Earth are among the most valuable fossil resources that nature provided for man. It is a crime against mankind to burn any of it.

(3) I don't believe that the U.S. chosen alternative to fossil fuel, namely, nuclear power, is proper. The nation is headed for very grave trouble with that alternative, a major part of it being economic. The costs of energy have risen dramatically in three years and will continue to rise. These then are the reasons I believe the nation needs a national wind-power program.

The major conclusions of my wind energy study are

(1) The wind is an enormous source of power, but we must go where it is, namely, high up, over 500 feet above the ground, to get it.

(2) It is incorrect to view and to cost out wind-powered systems solely as fuel savers. A self-contained storage system is needed, and power should be offered for sale on demand. The costs should be made on that basis.

The national wind-energy program I envision should consist of three general programs:

(1) A technology program whose objectives would be to improve the performance of components, reduce their costs, increase their life, and develop new concepts.

(2) A resource assessment program aimed at determining the energy potential of the nation's wind, the most suitable sites for wind power systems, and the effects of the wind systems on the local weather.

(3) A production plan program with the objective of using the nation's tremendous productive capacity to produce at reasonable costs the large number of wind power plants that are going to be needed.

In addition, an assessment should be made of the social, political, and legal problems associated with wind power.

The implementation of the wind energy program is also an important part of the overall program. One possibility, for example, is to suspend large numbers of small wind-generator units on cables like suspension bridges, or on other types of very tall towers.

In conclusion, my studies suggest that wind-powered energy systems have the greatest chance of being used to supply an important portion of the U.S. energy need in the near future at costs that are competitive with other available systems.

DISCUSSION

COMMENT: I don't think the professor has left us any questions really to ask. I am absolutely with him, really. If we look at the world as a whole and at the future of mankind, we must look more than 50 years ahead. (And mankind usually doesn't look more than 5 ahead.) I see a future in which our reserves are so low and our pollution levels are so high that the sort of life that is left is not the sort of thing that I want for my children, grandchildren, or greatgrandchildren. If we don't want that to happen, obviously we've got to do something now. Whether windpower is really the answer I don't know. The professor is a slightly more imaginative man than I, and I see perhaps more barriers than he does. But I am entirely with him, that wind power is one of the energy methods that we should develop now and as hard as we can.

Q: What is the relative height above ground level that you are contemplating these suspended windmills, and what logistics problems you might envision in a reasonably congested land area like the Northeastern corner of the United States? I could easily foresee a machine like this being used in Canada and I can see it in some of our uninhabited islands, but I really wonder, with people's addiction to small airplanes, glider clubs, et cetera, what legal problems you might see, in your immediate vicinity?

A: Well, let me take that last thing first. If we do have problems with small aircraft and gliders, then perhaps it's time that we make that choice. We shouldn't ignore these choices any more, and just because the FAA has allowed the small plane pilot certain privileges over the years is no reason why that has to continue. Now, that is the way I feel.

As for the sizes of mills or machines I studied, the system I put together for the off-shore wind-power system was based on two sizes of machines, because they were available to me: a 200-foot-diameter machine and a 60-foot-diameter machine. I copied the New York University report and was very happy to have their results. As I said, though, I have since come to the conclusion that in much of the United States smaller windmills will do. As a matter of fact, I promised a Senator from Wisconsin a study that is now a couple months late (but I'll get to him). In that study I've been looking at wind power supply in Wisconsin. Perhaps I can answer your question in that context.

On the north-south running highways, which run about 20 miles apart in Northern Wisconsin from Green Bay north on through upper Michigan, significant wind energy could be extracted using wind generators suspended over the highways. It is just as straightforward to talk about north-south wind barrages located over the woodlands between the highways. In this kind of wind barrage the axis height of the lowest machine would be 100 feet. We could suspend large numbers of wind generators in a suspension system whose towers would rise to some 600 feet. They would be, perhaps, cage-mast type towers with a

bottom so configured that they could straddle the highways. The span would be half a mile. The upper wires would drop from 600 to 300 feet. Now, on those wires we would suspend groups of vertical axes. Each axis, capable of turning to face the wind, would in turn carry the structural framework on which many machines, about 32 feet in diameter, would be installed - 20 kilowatt units. (Mr. Noel probably feels that he has made a convert. And I think he has!)

Q: Obviously you studied the Russian work that was done many, many years ago on that same thing. What is your opinion of that?
A: I think the Russians have done some very excellent work in wind power, but they aren't doing much of anything now. At least the last two to whom I spoke simply ignored it or wouldn't discuss it with us. They said it was entirely too old-fashioned for the Russians.

Q: They had looked at the grid system approach, hadn't they?
A: Yes, they had. In fact we could use structural grids. A very interesting study to make would be to go back to Grandpa's Knob and that design of a 175-foot-diameter machine (which I thought was magnificent), and substitute for it an array of 100 32-foot-diameter wind generators, each of 20-kilowatt capacity for a total of 2 megawatts installed capacity. This array would look somewhat like a big billboard, or radar mattress. They could be spaced far enough apart so that each machine could develop its wake fully, so we wouldn't suffer an efficiency loss there. How would this different 2-megawatt wind generator compete? I think it would do a lot better than the 175-foot-diameter machine did.

COMMENT: May I make a brief remark about the Russian effort? Very recently I did some intensive digging, talking to people in Washington and elsewhere about this alleged big wind power effort in Russia. Most of the Russians just smiled and thought I was rather primitive. They pointed out that they had built a few, but that they had so much hydroelectric power that they could run wires anywhere in the country. They don't need windmills.

COMMENT: I will just make an observation on the basis of the WKY towers. There is about a 40-percent higher wind velocity at 600 feet and about an additional 60 percent up to about 1000 feet.

COMMENT: Putnam, I think, came out with those figures quite nicely. He showed that you are really in the realm of diminishing returns by the time you go much above 150 feet. But I feel that you have to say, "Okay, so I'm in the realm of diminishing returns, but that's where the wind is. If I want to stay below it, I'm not going to get much wind." It's like those systems studies of fishing in the Gulf of Maine that said so conclusively that the most economic place to fish is in the street in front of the fish pier! The only problem is that the fish don't know that.

COMMENT: There is one point we must remember, unless you've thought of a new way of keeping your machines up there: The higher the tower, the more steel or some other metal you have to use. It takes some 13 200 kilowatt-

hours to produce a ton of steel and 50 000 kilowatt-hours to produce a ton of aluminum. We shouldn't waste energy in the structure before it's even built, there's no energy balance in that.

Q: How sensitive are your power costs in the final step of converting hydrogen to electricity if it's done by fuel cells. What lifetime energy have you amortized in the case of fuel cells?

A: It's quite sensitive in the case of the hydrogen fuel-cell link, though the most expensive portion of that system is the blades of the wind generators themselves. The second most expensive portion was the complete system from the electrolyzer through the fuel cell. Now, the fuel cell life I used was 15 years, and you go ahead and whistle! I know that some of you people keep saying that Pratt & Whitney really don't know what they're talking about. But I happen to have been in their lab off and on for many years, and I'm quite confident that the 15-year life is going to be achieved. In fact, this is just one aspect of the wind power system using a hydrogen link that I feel has a real future - all right, go ahead, shake your head! I'm sorry!

COMMENT: I think I have to answer that. I worked in the last 15 years in the field and I can't share their optimism that a 15-year fuel cell is around the corner. I've seen no test data from anyone that exceeds 2 years.

A: Someone thought enough of it about 4 months ago to assign them a $90 million R & D program.

COMMENT: I understand that some of our people are going to work on it. That's fine.

COMMENT: I would like to join him. Oklahoma State has had 10 or 12 years experience. You must know something we do not see in the published literature. I don't think a long-life fuel cell will come around in the next 5 to 8 years.

A: I know of one New England utility who is purchasing from Pratt & Whitney right now a considerable number of kilowatts of hydrogen-air fuel cells at a total cost of $185 a kilowatt, which includes reformer. Now, I don't know the life specs, but I'm sure that it's at least 15 years. Now that's as much as I know; you've got me in over my eyebrows!

The most significant work in fuel cells perhaps has not been - and this is really going to hurt - the NASA work of the last few years, but the U.S. Navy work which created the fuel-cell power system for the deep ocean search vehicle. Those results are not available to all of us.

COMMENT: Bill, I think you have released a flood of philosophy here, which I think is not unwelcome. I am frequently called on to address groups on the subject of the energy crisis and the like, and I have been using a subtitle to my talk. Usually it's something having to do with the resource crisis. I think it's appropriate this afternoon to mention

it and perhaps coin a new phrase.

What I am referring to is that in any resource pinch such as that in which we find ourselves now, our criteria have got to change very rapidly. The escalation of the energy crisis really took off essentially like a rocket in about 1969. Many of us take a good deal of comfort in looking at the average cost of energy curves. Though the average costs are up from 1969, they are still artifically depressed by the fact that some of the energy contracts in force today were negotiated several years ago. If you look very carefully at the current contracts, you will see that a cost of about 90 cents per Btu is fairly common. Those are the numbers we should look at, not the averages.

Now, when Bill speaks of suspension via hydrogen balloon or cables or towers, or what have you, I don't think it's exactly pertinent to point out that aluminum takes so many kilowatt hours per ton and steel so many. These are one-time costs, and they can be energetically amortized.

Now, the subtitle to which I refer and which I think is appropriate today is, "Don't worry about Mars and Venus. The question is 'Is there intelligent life on Earth?'"

I would also like to add that, if we assume that our present point in history is perhaps 5000 years removed from the first time man recorded things by infusing them on stones, perhaps this generation has another five thousand years. The fossil fuel era, through which we are presently half way through and passing very rapidly, I very inelegantly refer to as a small pimple on the rear end of history.

I think it would also be appropriate for us to ask ourselves something to the effect that (I think the word "war criminal" was coined during the latter stages of World War II) "Are we behaving as "resource criminals," because we're using it up just as fast as we please without a thought to where it ends and what our children and their children will have to do with when their time comes?"

COMMENT: If you are brainstorming, you can come up with all kinds of designs for windpower plants. I could surprise you by some of the ideas. For example, if you put a heavy rotor on a tower and put a rope on it and drive it, it will go higher up in the air. Then, if you fix the next one then you can put both rotors up in the air to the stratosphere.

This is just one of the hundreds of ideas that could be mentioned here. The solution to accumulate many rotors on a system of steel ropes or something like that has been brought up by Russia and by Holland in the middle of the twenties. Going in this direction is a market question.

Let me mention one thing, which is the best size for wind electric power. This is an important question. If you make small ones, you can produce them in quantity and get the advantage of a lower price by their small size.

If you make big ones, you get advantages of the fewer parts and there is somewhere a minimum of the cost, and we have to be very careful to do this. We can calculate the minimum.

A: Doctor, I think some of your fellow engineers have designed very distinctive wind generators. I am not sure I could contribute anything.