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THE ROLE OF NUCLEAR ENERGY

by Edward Teller

Born in Hungary in 1908, educated in Germany at Munich and Leipzig, Dr. Edward Teller has held posts in many of the world's most distinguished universities and research institutes. A citizen of the U.S. since 1941, he played a key role (with Manhattan Project colleagues) in the development of America's nuclear capabilities and has been consulted on atomic energy matters by most of our presidents since World War II. He is presently with the Lawrence Livermore Laboratory at the University of California.

Honorary degrees from Yale, Fordham, George Washington and St. Louis universities (among others) have accompanied awards given for distinguished service in science, including the Joseph Priestley Memorial Award (1957), the Albert Einstein Award (1959), and the Enrico Fermi Award (1962).

He has authored numerous volumes, and most recently has been active in the development of the Sherwood Project (the controlled thermonuclear program) and in the development of Project Plowshare (involving the peaceful uses of nuclear explosives), as well as astrophysics and molecular physics.

Dr. Teller delivered this presentation at Hillsdale College as part of the Center for Constructive Alternatives seminar titled "Energy or Exhaustion: The Planet as Provider."

Right now I am working on the Commission on Critical Choices for Americans under the chairmanship of Nelson Rockefeller. And furthermore, the topic of my work is energy. Some of us have seen the energy shortage coming. Had we done the right thing about it, there would not be an energy shortage now. The oil embargo came just a little less than a year ago. This year we have wasted. We have made practically no progress toward solving the energy shortage. And the energy shortage must be solved.

You have heard this from others: each year a hundred billion dollars are paid to the oil producing countries who can use only 40 percent of that money. The rest remains floating capital. The accumulation of this capital will transfer an amount of wealth to these countries which in ten years will amount to the value of everything that you can buy on the New York Stock Exchange. And it will be six times the value of the world's gold reserves. If this is not unstabilizing, I don't know what is. I don't know what will happen, and in this respect I'm just as good as the economists. They don't know either. But the disorder that may come could be bigger than that connected with the great depression. The great depression led to Hitler, and Hitler made the Second World War.

We have in the United States an oil shortage which we can live with, although it might be disagreeable. The Europeans, the Japanese, many of the developing countries including India, cannot. The problem is a global one. And our main concern should not be ourselves. Our main concern should be how the effect of unemployment, hunger, other disasters occuring around the world will react back on us. That may drag us down. There is no *one* solution, and whoever claims that there is one solution, I am sure that he is either a liar or a fool.

One of the things that can be done fastest and should be emphasized most, is conservation: to use less energy in every possible way. There are many other approaches, and you have heard some of them. I will concentrate on nuclear energy, not because it is *the* solution, but because it is a very big part of the solution, and because I happen to know about it more than I know about the other problems. So I talk about what I know.

For us in the United States nuclear reactors are important. In ten years they could deliver more than one-third of our electric power. In 20 years if we go about it the right way they could deliver well over one-half, maybe three-quarters of our electric power.

im•pri•mis (im-pri'mis) adv. In the first place. Middle English, from Latin in primis, among the first (things). . .

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And that is what we should be aiming for. If we abstain from building nuclear reactors it will be harder, but we shall not be faced with insoluble problems.

There are many places in the world where nuclear reactors are a must. For instance, this holds for Japan, which has no oil, which has very little coal, and which probably has geothermal energy that is still to be developed.

Nuclear energy has one peculiar property in common with oil and one property different from oil. Both are favorable for nuclear energy. The common property is that nuclear fuel can be transported even more cheaply than oil, although oil can be transported very cheaply. Coal and liquid natural gas are much harder to transport. Nuclear fuel is available in very many places around the world in abundance. We are not going to run short of nuclear fuel, and this is the second point where I say nuclear fuel is different from oil. An oil shortage, if it is not here yet, is coming. The Arabs, the Iranians, could pump out oil more rapidly. Probably they should – perhaps we can persuade them to do so. But in 20 years or 40 years these supplies are apt to run short. Nuclear fuels are going to last at least for 100 years, and I believe much longer.

Now here I come to a somewhat controversial point. It is not a point about which the broad public is getting excited. But in the technical public it is controversial and it should be understood. It has been claimed that the kind of nuclear fuel that we are now using will be short, certainly in 20 years, perhaps a little sooner. And, therefore, we have to develop a new type of reactor, a breeder reactor. Now the breeder reactor has this advantage: instead of using only approximately one percent of the energy in the uranium, it can use close to 100 percent of the energy. And you can gain in principle a factor 100. This was known in 1945. No new idea has been added. The engineers have been busy all around the world. A couple of billion dollars have been spent, the best talent has worked on it, we still have no breeder. It happens to be a really difficult problem and nobody believes that we are going to have a fast breeder before 1990, at least none that can make a real difference. And we need the energy now.

There is a solution: uranium is not the only fuel. There is another element in the close neighborhood of uranium, called thorium. Thorium can be used as a supplementary fuel. It can take over at least 80 percent of the energy production in reactors similar to those we have today. These reactors don't need the long research that the breeder needs, and if we utilize this possibility then we are going to have enough fuel for everybody in the whole world for at least 100 years. I guess that it might turn out in the end to be closer to 500 years. In the meanwhile, all kinds of other things will be developed. So that point needs not worry anybody.

There is another point about which people are very worried: the nuclear accident. Now this is very peculiar. I have a little personal involvement with this point. Around 1950 I was chairing the

world's first Reactor Safeguard Committee. And at that time, among my colleagues who wanted to build nuclear reactors very fast, I was known as something like a "Mini-Nader" (although that expression at that time didn't exist yet. I will gladly concede that Nader is bigger, but I will not concede that he is necessarily better). We tried and succeeded in making reactors exceedingly safe.

A nuclear reactor can go wrong in many ways, although none has ever gone wrong yet. All these accidents are imaginary. And by imagining them we are avoiding them. We have no precedents. We build cars, let them collide, get into trouble and then find the safety measures. With the reactors you better not do this, and we haven't.

I want to give you an example from the early days, a very simple one. A reactor came up for consideration on Long Island, to be built in a place to be called Brookhaven. Now this reactor consisted of two big pieces, and between them there was an open slab in which the cooling air was to come out. I started to get nightmares. What if Long Island had a very big earthquake, and the two pieces slid together? Then the darned thing would be more than critical, it would blow up. Now I didn't quite say that. I didn't quite imagine that, because that couldn't happen. They could slide together, the reactor could develop too much energy and ruin itself. But it would not blow up, even under the most extreme conditions. It cannot blow up, because it is not constructed that way. You have to be very careful to construct a nuclear device in such a way so that it should blow up. We had a hard time in persuading nuclear devices to blow up in Los Alamos. A reactor won't even do it for us. But the reactor could ruin itself and a lot of radioactivity could get loose, and that's what I was worrying about.

So our committee asked an earthquake expert to come and talk to us. You may know that the best earthquake experts in the United States are the Jesuit fathers. Their missionaries in China used seismology to tell the Chinese emperor where the earthquake would occur, before he could have any message, which was, of course, miraculous, or divine. And the Jesuits made much of it. So a small Jesuit father, who incidentally could not be cleared for the secrets of the reactors (because in those days the reactors were secret) came to us under guard in the AEC. They sat him down at the head of the table in a big armchair, the little father, and he kept answering questions for half an hour. In that period we ran out of questions, but he did not run out of answers. When it was clear that no more answers were coming he pulled himself up in the chair, growing in stature, and looked us in the eye one by one. He looked at me last and said, "Dr. Teller, I can assure you on the highest authority that no major earthquake will occur in Long Island in the next 50 years." He got up and marched out of the room. That was the most difficult moment of our committee, but we behaved grandly. There was not a single smile until the door closed after the Jesuit father. And he had it on the highest authority, just like the Jesuits in Chinese imperial days.

I tried to tell this to you because there is this mixture of the unreal and the very real, the very practical, which we run into. More and new difficulties can be imagined. We don't want a nuclear accident and we should never have one. I have advocated, and I am still advocating, that nuclear reactors should be built underground. They are exceedingly safe, but they should be even safer; this should not mislead you into believing that the reactors are not safe as they are. The urgency of the present situation is so great that we should build them.

Let me try to tell you of two little points. No industrial nuclear reactor has killed anyone yet. The critics of nuclear reactors have the highest of praise for hydro electricity—for dams. The collapses of dams have killed hundreds of people and have made many more thousands homeless.

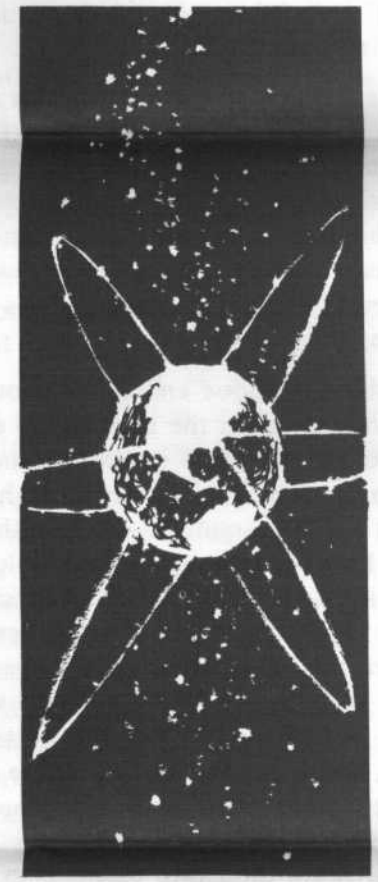
As another example, we are running short of natural gas. We begin to practice the importation of gas in the form of liquefied natural gas (LNG) in big ships. It is conceivable that such a ship may blow up. Not long ago two railroad cars carrying butadiene blew up in Houston with the force of many tons of TNT. Many people were hurt, and windows miles away were broken. Liquefied natural gas, because it has a lower boiling point, is more dangerous then butadiene, and a big ship is very much bigger than the two railroad cars. You have right there enough energy to supply five Hiroshimas. I don't know whether it can happen, but it can happen much more easily than a malfunction of a nuclear reactor. Do not believe that anything we are doing is safe.

In the special case of nuclear reactors there is an aura of danger which quite possibly comes from the fact that we are uneasy about what happened in Hiroshima, which probably shouldn't have happened. We probably should have tried to end the war with a demonstration, rather than with killing people. That nuclear energy first was used in war has colored our thinking on the subject.

Nuclear reactors are safe. Nuclear reactors are generally available. Unfortunately, they cannot be built quickly. Today it generally takes ten years to build a nuclear reactor, although we could speed up the building of nuclear reactors to five years. In the meantime there will be serious shortages.

Now let me talk about these reactors a little more. Even if I do that I will not manage to exhaust the criticisms of nuclear reactors. One of the criticisms is that nuclear reactors emit radiation even in their normal operation, and that this radiation may endanger people. I have a colleague, Dr. Tamplin, who appeared at a hearing of the Dresden III reactor and objected to the Dresden III reactor because it emits radioactivity in normal operation. A young employee

of the AEC who was present at the hearing asked Dr. Tamplin, "From what do you get more radiation, from leaning up against the outside of this reactor, as close as you can get, for a full year, or from your habit of sleeping each night with your wife?" Dr. Tamplin did not seem to understand. So the AEC man explained. "I am not trying to imply that your wife is particularly dangerous. But all of us have radioactive potassium in our blood. And you get more radiation from your own potassium than you get from the gamma rays that your wife's potassium emits. But you get some from her. Now then, potassium is well shielded; so is the radio-



activity of this reactor. Just for comparison, from which do you get more radiation?"

Dr. Tamplin still couldn't answer, so this AEC man went back to Washington and wrote a memorandum, and forgot to classify it, and I got a copy. This memorandum said, "I have made the calculation, and you get more radiation from the Dresden III reactor than you get from your wife. Therefore, I am not going to suggest to the AEC that twin beds should become obligatory for all married couples. But from the point of view of radiation hazard, I must warn you against the habit of sleeping each night with two girls, because then you get a little more radiation than from the Dresden III."

Probably I should not talk this way because we are speaking of extremely serious problems. But you should realize that at a time when more energy, including more energy from reactors, has become practically a matter of life and death, objections as trivial as the one I have just mentioned are being raised and are believed. I think reactors can be built, must be built, and I am confident will be built. I hope they will be built safely.

It has been proposed to produce energy not from nuclear reactors, which derive their energy from the splitting of heavy atoms, but from controlled fusion, with the energy from the union of the lightest atoms – that is, on fusion of hydrogen. Fusion was used in an explosive form in the hydrogen bomb. The question is whether we can use it in a controlled form to produce energy.

I have been arguing that all research on fusion should be open. After many years of argument I got permission to go to the second Atoms for Peace conference and talk about it publicly. The Russians came and talked about it too. It is now a subject of internal cooperation which is a complete success. We have good reason to be convinced that even the Russians don't hold back. They are working on it more diligently than we are.

Unfortunately, the problem is difficult and we will not succeed in my opinion before the year 2000. It may succeed in the next few years in the sense of building a demonstration plant which gives an electric profit, meaning more electricity would be produced than consumed. An electrical profit, however, is not a dollar profit. It will be a big engineering job to make fusion economically usable. It cannot be done before the year 2000. The same holds for the much more ingenious and much more difficult idea of laser fusion.

We started to talk about fusion at an international conference in 1958. And while I was at it I also got permission to talk about a proposal we had in our laboratory, the Livermore Laboratory – a proposal to use nuclear explosives for peaceful purposes, which I briefly did in Geneva in 1958. No sooner did I finish than Professor Emilianov, the leader of the Russian delegation, got to his feet and denounced our proposal on Plowshare (the peaceful use of nuclear explosives) as an imperialistic plot designed to legitimize more nuclear explosive experimentation. With an enormous exercise of self-control I refrained from answering him. But a few hours later in the press conference, a reporter from

New York asked him, "Isn't it true, Professor Emilianov, that at the time of the first Russian nuclear explosion in 1959, a member of the Politboro claimed that this explosion was not for war, but for peaceful purposes? Now you say that nuclear explosives cannot be used for peaceful purposes." The professor said, "That was a politician speaking, and we Russian scientists never listen to what the politicians say."

I have to tell you that in the meantime the Russian scientists seem to have listened. We are not progressing on Plowshare because some people who believe they are environmentalists are objecting. The Russians are going full speed ahead. They have used nuclear explosives to put out fires in gas wells. They drill a hole next to the gas well, explode the nuclear device and shove the earth over in a massive explosion, and that shuts off the burning. They have made a big hole in the desert as a water catchment area. They are planning to connect two rivers, the Pechora and the Kama, which flow westward from the Ural mountains. One, the Pechora, flows into the Arctic Ocean, which has enough water. The Kama flows southward into the Volga and eventually into the Caspian. The Caspian is drying up – it's too salty. Fish don't thrive so well and the Russians are getting a little short of proletarian caviar. They are planning in a very reasonable environmental fashion to deflect the Pechora into the Kama, which means digging a long canal over elevated terrain, which you can do by nuclear explosions – a very admirable project.

Now all this has a recent sequel. You know that the Hindus have exploded a nuclear device. They claim they are doing it for peaceful purposes. They furthermore claim that they have done it in shale because they want to squeeze oil out of oil shale. They say that nobody should object. In principle they may be right, but in practice, who knows?

But what about this question of squeezing oil out of oil shale? Nuclear reactors will solve a part of the energy problem. But as we now know the subject, nuclear reactors will mainly produce electricity. They will not produce a fluid that can be used to drive automobiles. Shale (peculiarly enough) does not contain any oil, but it has organic substances which if cooked make a fluid which looks like oil. You can think of oil attached to rock: that is oil shale. The cooking tears the oil loose from the rock. The approved method is to dig up the oil shale, put it into a retort, ignite at the top, and it will start to burn down if you supply oxygen or air. As the burning progresses downward, layer after layer is heated. As the layer gets sufficiently heated, the oil is liberated and vaporizes. The vapor then condenses in the layer even lower down. And this oil can be pumped out. That is how oil shale gets retorted today. But first you must dig it up, and then you must retort it – very expensive. Furthermore, it takes a lot of steel, a lot of capital investment. And in order to do that we have to get hundreds of thousands of people to Colorado, Wyoming and Utah, into desert places – a big displacement of population. And we must use lots of water to cool the retorts. And then you are left each day with millions of tons of unused shale, which is a real environmental nuisance.

Now one of my acquaintances, Don Garrett, has proposed a way around these troubles. He excavates a room below the oil shale, then puts high explosives into the ceiling, collapses the ceiling, and produces a rubble chimney in the oil shale. Then he uses this chimney as a natural retort. He does the whole thing underground. It is cheaper, it is better, and it should be done.

I don't think it's good enough. It should be done, but the development in the end will go even farther. In Colorado, in one place in the Piceance Basin, we have approximately two A units of hydrocarbon. An A unit is the amount of oil that the Arabs are known to have underground. And Colorado has at least 2 A units, probably more. And some of it is 2,000 feet thick. What you can do here is to drill down under the shale, blow up a nuclear explosive, maybe 50 kt., maybe 100 kt. There would be an earthquake on the surface, so you better move the people out. But it is a desert area where for one shot you have to move out maybe 50 people. And the damage found afterwards in the few buildings is quite small. It's a moderate earthquake, not a very big one. Then you are left with an enormous rubble chimney. You have saved the whole mining operation, you have brought out no shale, everything is underground. You might get oil as cheaply as $3 to $5 a barrel in great quantities, enough for us for the next 100 years. Furthermore, oil shale in one form or another is widely distributed throughout the world. The Plowshare method is only one way – it may be the best.

Yes, but some people have proposed an amendment to the Colorado constitution: no nuclear explosions in Colorado. I am told the amendment will pass.* I am told I better not go to Colorado and speak there, because I am a carpetbagger with an accent,

and it will only make matters worse. But I'm going just for the fun of it.

I have told you the story about oil shale, about the Hindus, about the Russians, and about our own efforts to try to give you an idea how many ways there are in which the energy problem can be handled. And I can assure you that there are a dozen other possibilities which I haven't mentioned.

I am firmly convinced that we must try to work on many fronts. On those that will pay off later, we still should work a little.

Furthermore, I am convinced that we must not go into this research and development by ourselves. It is a worldwide problem. It should be attacked on an international basis, which indeed is already done in connection with controlled fusion. We have not done it in connection with the breeder reactor. The job should be performed jointly. Plowshare should be jointly pursued. It should be open. The Hindus may learn a little from us, and I would be very happy to learn, in turn, from the Hindus and the Russians. It is a problem as important for them as it is for us.

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*It has passed.