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FEATURING

Steven Chu

Director of the Lawrence Berkeley National Laboratory

BASIC

BAY AREA SCIENCE AND INNOVATION CONSORTIUM

Innovators

SERIES

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S E R I E S

Innovation matters. As the late great scientist Stephen Jay Gould showed in his studies of evolution, being at the forefront and establishing a niche is a key to competitiveness. The San Francisco Bay Area has earned a vaunted reputation for being one of the nation's regional leaders in technological innovation. It is home to five national scientific laboratories and a host of other federal and non-profit research facilities, some of the country's finest research universities and top private industry R&D firms, and a plethora of cutting-edge start-up technology companies. This abundance of R&D capabilities, in combination with a proud history of intellectual openness and a pioneering spirit, has drawn many of the nation's brightest minds and scientific talent.

Bay Area scientists and engineers are striving to uphold the region's reputation for technological innovation by serving at the vanguard of exciting new research in a wide range of fields, including biology, advanced materials, energy and computation. Breakthroughs in any of these fields hold forth the promise of a bright and prosperous future for the region, the State of California, and our nation as a whole. In the BASIC Innovators Series, key Bay Area innovative thinkers share their thoughts on the science today that will lead to the technology of tomorrow.

BASIC Innovators Series

An Interview with

STEVEN CHU

Director of the Lawrence Berkeley National Laboratory, and winner of a Nobel Prize in Physics in 1997 for the development of methods to cool and trap atoms with laser light.

One of the most prominent and vocal of all the scientific figures to address the energy crisis is Steven Chu, who shared the 1997 Nobel Prize in Physics for his role in developing techniques that use laser light to cool and trap individual atoms. After 10 years at AT&T Bell Laboratories in Murray Hill, N.J., where he performed advanced experiments in laser spectroscopy and quantum physics, and 17 years at Stanford University, where, among many other achievements, he helped initiate and oversaw construction of Bio-X, a facility that brought together researchers from the physical and biological sciences, he is now the director of the Lawrence Berkeley National Laboratory (Berkeley Lab). Located in the hills above the University of California's Berkeley campus, Berkeley Lab is a U.S. Department of Energy national laboratory that has been at the forefront of science and engineering research for nearly 75 years. Chu has made good use of his Nobel laureate scientific credentials and his leadership position at Berkeley Lab to champion the cause of finding energy alternatives to fossil fuels that are sustainable and environmentally sound. To raise public awareness and help separate fact from spin, he has served on blue-ribbon scientific panels, met with government leaders, written editorials and granted numerous interviews. A collection of Chu's thoughts and comments is presented by BASIC in the following Q and A.

BASIC: The energy crisis is one of those scientific topics, like global climate change or stem cell research, where the public commentary by experts is often contradictory. You, however, have consistently stated that energy is the single most important problem that science and technology must solve in the coming decades. What's your reasoning?

STEVEN CHU: The worldwide consumption of energy has nearly doubled between 1970 and 2001, and is expected to triple by 2025.

Meanwhile, the extraction of oil, our most precious energy source, is predicted to peak sometime within the next 10 to 30 years, and most of it will be gone by the end of this century. In a little more than 200 years of industrialization, we have consumed what took hundreds of millions of years for nature to make. We need to find a replacement for oil before it runs out. Natural gas is not the answer because it will follow a fate similar to that of oil. Other forms of fossil fuel, such as coal, shale oil, tar sands and methane hydrides, could last for several hundreds of years. However, the use of each of these fuels poses technological problems, starting with the contributions of greenhouse gases to global warming.

BASIC: With respect to global warming, you're also known as somewhat of a crusader for finding energy sources that are carbon-neutral. What has convinced you that anthropogenic activities are impacting the global climate?

STEVEN CHU: I'm not alone in my beliefs. It is the overwhelming consensus among scientists that the Earth is warming and that the emission of greenhouse gases, such as carbon dioxide, through human activity, is a significant factor.

You can draw a parallel to the research into cigarette smoking, during the 1950s and 1960s, where scientists found a link between cigarette smoking and lung cancer. We don't know the exact consequences yet as to how burning fossil fuels affects global warming, but we can guess they're pretty serious. Take some of the current computer climate modeling simulations that in the Midwest, the temperature will increase 5 to 10 degrees Fahrenheit on average. Hotter summers mean a growing season in which the soil moisture will decrease by 20 to 30 percent. Simulations are not proof, but if you take them at face value, then the great agricultural machinery of the U.S. is at risk, with huge economic consequences. That's what makes new investments in fossil energy technologies, such as conventional coal-burning plants, a questionable strategy. Projections show that over the next 30 years, the burning of fossil fuels will add three times as much carbon dioxide to the atmosphere as we have added over the past 250 years.

BASIC: So what we need are energy-sources that are renewable and carbon-neutral and economically practical enough to supplement or replace fossil fuels. Is there a silver bullet out there that can solve all our energy problems?

STEVEN CHU: No magic bullets to solve the energy problem seem to be on the horizon. Instead, we're going to have to look to a diversified portfolio of investments. Fission energy should certainly be part of that portfolio, but it comes with legitimate concerns about long-term waste storage and the potential proliferation of nuclear weapons materials. Still, fission energy looks good compared to conventional coal-burning plants. Fusion energy is a possibility, but commercially viable fusion is not a certainty and at best is many years away. Modern wind generation is becoming economically competitive, but it will never be able to supply the majority of our energy needs. Solar energy is probably the single best candidate in the portfolio, but photovoltaic generation needs substantial improvement in cost and efficiency before large-scale deployment can occur. It will also be essential to develop efficient methods to convert electricity into stored energy that we can use on demand. However, there is another approach to converting solar to chemical energy, and that is through biofuels.

BASIC: The biofuel approach seems to be the one that has captured your attention. Why do you favor going down that particular road?

STEVEN CHU: For billions of years, nature has been using photosynthesis to effectively and efficiently turn solar energy into chemical energy. If we can learn to mimic biological systems, in conjunction with other advances in molecular biology, we can take a significant step towards solving our energy problems. For example, with sufficient conversion efficiency, we could replace gasoline with biofuels to meet our transportation energy needs using only about twenty-five percent of our arable land, most of which farmers are being paid not to grow crops on. Of course, we'll need to develop plants that are self-fertilizing, don't require much water and grow like crazy, and are also exceptionally good at converting carbon dioxide, sunlight, water and modest amounts of nutrients into biomass. Then we need to develop more efficient means of converting that biomass into usable forms of energy.

BASIC: Is that where "termite guts," another expression you've made famous, come into play?

STEVEN CHU: Termites have developed a symbiotic relationship with colonies of bacteria that reside in a termite's gut and convert biomass, specifically cellulose, mostly from wood, into chemical energy the termite can utilize. If we can learn to either genetically engineer the microorganisms from termite guts, or cow guts, or those found at the bottom of a swamp, to produce more energy from biomass than they need, or else adapt the chemistry within the microorganisms to process the biomass ourselves, we would go a long way towards reducing our dependency on other countries for oil. There's a lot of biomass out there and if we're ever going to raise crops for energy, it's not going to be for the oil we can extract from the corn or the sugar from the sugar cane that we can convert to ethanol, it's going to be for the entire biomass of the crop.

BASIC: What is your response to arguments that say we should not take farmland out of crop production and use it for energy production, especially if the biomass is to be converted to methane which emits greenhouse gases when burned?

STEVEN CHU: First, we have a substantial amount of arable land we're not using to grow food, so why not use it to grow fuel in a way that doesn't consume a lot of resources? Ideally, we should look to increase the efficiency of how we use land, water, and input energy in the form of fertilizers, harvesting and distribution energy, and the energy required to convert biomass into a more usable chemical fuel. If we raise the efficiency factor by two or three in these areas, we could easily use half our agricultural capacity to grow energy with no drop in crop production. Second, when you raise crops for energy, you're actually combining carbon dioxide with water, some nutrients, and sunlight to make a carbon-based fuel. If you burn that fuel efficiently, it's a closed cycle: you take carbon dioxide out of the atmosphere to make the fuel and burn it to release it. The cycle therefore just goes round and round in a carbon-neutral circle, as opposed to what we currently do with fossil fuels, which is to extract them out of the ground, burn them and add new carbon dioxide to the atmosphere.

BASIC: You were a member of a recent National Academies' committee which, among other recommendations, called for the U.S. Department of Energy to create an Advanced Research Project Agency – Energy that would sponsor "out-of-the-box" energy research. Can you give an example of an "out-of-the-box" energy research project?

STEVEN CHU: At Berkeley Lab we think a solution to the energy problems may lie at the interface between biology and the physical sciences on the nanoscale. We are now mounting a major, multidisciplinary initiative, which we call Helios, which would develop ways to convert solar energy into a carbon-neutral form of energy that could sustain our world in an environmentally friendly manner.

To do this, we are drawing on our expertise in nanotechnology and synthetic biology, and the resources that are now available at the West Berkeley Biocenter, which was formed in partnership with the University of California at Berkeley, and at The Molecular Foundry, a U.S. Department of Energy nanoscale science research center that is now under construction at Berkeley Lab. We believe that a well-conceived program put in place now has the potential to provide the people of the United States with renewable energy security and economic growth for decades to come.

BASIC: You began your own research career as a physicist, but in recent years your interests seem to lean more towards the biological side of science. For students interested in a scientific career today, what fields would you recommend?

STEVEN CHU: The career field that is most important is the one that you are most passionate about. Passion will get you through many a long night in the laboratory or in making calculations. Beyond that, you must get an early foundation in math and quantitative methods. Regardless of the science field you finally choose, whether it's physics, biology, biophysics, or new fields not yet devised, you must understand the underlying concepts of mathematics. And, you can only use mathematics as an effective tool in your science if you learn it early in life. Don't wait until you're thirty. ■

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