In memory of Richard Smalley

Chapter 2

Nanotechnology and Our Energy Challenge

Richard Smalley

I've increasingly begun to believe that a grand challenge before us—the world and humanity—is what I call "the terawatt challenge." I've been looking into the energy issue and I've been on a quest for terawatts, or trillions of watts of electricity. What I'm looking for is to solve what I believe is the most important problem facing humanity, the problem of generating energy of the magnitude that we will need in this century for what could very well turn out to be ten billion people on the planet.

Energy is the single most important challenge facing humanity today. As we peak in oil production and worry about how long natural gas will last, life must go on. Somehow we must find the basis for energy prosperity for the twenty-first century. We should assume that by the middle of this century we will need to at least double world energy production from its current level, with most of this coming from some clean, sustainable, carbon dioxide–free source. For worldwide peace and prosperity, it must be cheap.

Energy is a $3 trillion a year enterprise, by far the biggest enterprise of humankind. The second most important is agriculture. It used to be that agriculture was almost everything, but agriculture is now only half of energy. All of Defense, both in the United States and around the planet, is only $0.7 trillion. I want to find a new oil, an energy source that will do for this century what oil did in the last century.

I have asked audiences across the country, "What do you think deserves to be on the list of world problems?" My hypothesis is that if you gather any group of people together the word *energy* will always appear on this list. I've done this with fourteen independent audiences, and energy, phrased in one way or another, is one of the first problems suggested.

World Problems

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism and war
7. Disease
8. Education
9. Democracy
10. Population

My second hypothesis is that if you solve the energy problem you will find that at least five of the remaining nine problems on the list now have a path to an answer that's acceptable, whereas in the absence of solving the energy problem, it is difficult, if not impossible in most cases, to have imagined an answer.

Water is a very brutal problem. Either you've got it or you don't. Luckily, on our planet, there's plenty of water. In fact, we probably have more water than anything else. But it has salt in it, and it's often thousands of miles away from where we need it. We need it in vast amounts, hundreds of millions of gallons a day. We can take the salt out of the water. There's no doubt some nanotechnology that will do it at 100 percent efficiency or close to it, or you can just boil the water. You can do it if you find the energy. And you've got to put it in a pipe and pump it to where you need it, which might be thousands of miles away. We can make pipes and we know how to pump them, but it costs energy to make them, it costs energy to maintain them, and energy to pump the water from here to there. We can do it. If we have the energy, we can solve the water problem. Just solve it, for ten billion people everywhere in the planet. If you haven't got the energy, you can't solve the problem.

The third one on the list is food, which is going to be an increasing problem on our planet. We need agriculture and we need water. So if you solve the water problem, you've gone a long way to solving the food problem. In addition to food and water, you need fertilizers. You need energy for that. We need to have a structure where we harvest food and move it around. We need energy for that also. If you've got energy, you can hack this problem. If you don't have cheap, fast energy, I don't see how you can solve the problem.

Virtually every aspect of our fourth problem, the environment, has directly to do with either the way we generate energy, where we get it, how we store it, or what happens when we generate it. I don't know of any other single thing, if you care about the environment, that would have a bigger positive effect than to solve the energy problem. I don't know of anything else you could do for the environment that would be more effective.

Energy would have a tremendous impact if you could solve it—make it cheap, make it abundant, find a new oil. Miracles of science and technology in the physical sciences are primarily what enables this.

My third hypothesis is that no matter what you suggest as being items that deserve to be on this list of the top ten, if you take something other than energy and move it to the top, you will not find anywhere near the same cooperative, positive effect on the other ones as energy.

So you look at where the power is available, the true energy source that's available to generate terawatts. It turns out it's very simple. The big place where we can get the terawatts we need is in the place where there might as well be nothing right now. The technology that enables that has to happen a lot sooner than 2050, because of the huge size of the population. So this is what I call the terawatt challenge: to find a way of changing the energy source so that we can still be prosperous.

It's actually not clear that there is enough coal that's really efficiently, cheaply producible. It's interesting that when you look for terawatts, all the other answers are nuclear. Solar energy is a nuclear energy source, of course. Thus if you like nuclear and if you like nuclear fusion, you'll love the sun. Every day, even though vast amounts of the solar energy go someplace else, 165,000 terawatts hit the Earth. We need only 20 terawatts to completely solve the world's energy needs. This is a vast energy source. We just don't know how to get it cheaply yet.

TRANSPORT AND STORAGE

I've done a lot of thinking about this, trying to think of some scheme for energy around the planet that actually makes sense, technologically and economically, that's up to this terawatt challenge we have. I call this idea the distributive storage grid. In the year 2050, instead of transporting energy by moving masses of coal or oil, you transport energy as energy. You do that with a grid of electrical connections, an interconnected grid of hundreds of millions of local sites.

Consider, for example, a vast interconnected electrical energy grid for the North American continent from above the Arctic Circle to below the Panama Canal. By 2050 this grid will interconnect several hundred million local sites. There are two key aspects of this future grid that will make a huge difference: (1) massive long-distance electrical power transmission and (2) local storage of electrical power with real-time pricing.

Storage of electrical power is critical for the stability and robustness of the electrical grid, and it is essential if we are ever to use solar and wind as our dominant primary power sources. The best place to provide this storage is locally, near the point of use. Imagine that by 2050 every house, every business, every building has its own local electrical storage device, an uninterruptible power supply capable of handling the entire needs of the owner for 24 hours. Because the devices are, ideally, small and relatively inexpensive, the owners can replace them with new models every five years or so as worldwide technological innovation and free enterprise continuously and rapidly develop improvements in this most critical of all aspects of the electrical energy grid.

Today, using lead-acid storage batteries, such a unit for a typical house to store 100 kilowatt hours of electrical energy would take up a small room and cost more than $10,000. Through revolutionary advances in nanotechnology, it may be possible to shrink an equivalent unit to the size of a washing machine and drop the cost to less than $1,000. With these advances the electrical grid can become exceedingly robust, because local storage protects customers from power fluctuations and outages. Most importantly, it permits some or all of the primary electrical power on the grid to come from solar and wind.

The other critical innovation needed is massive electrical power transmission over continental distances, permitting, for example, hundreds of gigawatts of electrical power to be transported from solar farms in New Mexico to markets in New England. Then all primary power producers can compete, with little concern for the actual distance to market. Clean coal plants in Wyoming, stranded gas in Alaska, wind farms in North Dakota, hydroelectric power from northern British Columbia, biomass energy from Mississippi, nuclear power from Hanford, Washington, and solar power from the vast western deserts. Remote power plants from all over the continent contribute power to consumers thousands of miles away on the grid. Nanotechnology in the form of single-walled carbon nanotubes (aka “buckytubes”), forming what we call the “Armchair Quantum Wire,” may play a big role in this new electrical transmission system.

Such innovations—in power transmission, power storage, and the massive primary power-generation technologies themselves—can come only from miraculous discoveries in science, together with free enterprise in open competition for huge worldwide markets.

The key is not only an energy source but also energy storage and energy transport. If you can solve the problem of local storage, you've basically solved the whole problem. That's because, by definition, the storage you need is local. You've got terawatts of power moving into the grid. The biggest problem with renewable energies in general, and solar and wind in particular, is that they're episodic and not dispatchable. You've got to have storage. Storing energy in batteries, capacitors, fuel cells, and some chemical systems like hydrogen depends on nanoscale interactions. It depends on charge transfer reactions that take place over the span of a few atoms on their surface. The next generation of storage devices are all optimized by nanoengineered advances and the use of nanoscale catalyst particles. Nanotechnology is where the action is in energy storage.

ENERGY FOR EVERYONE

So in summary I believe that if you had to pick one issue that's more important than any other single issue, it is energy. You could have picked any issue, but energy is something we can do something about, and if we do it, we can affect positively most of the other problems facing us.

The task would be supplying energy for ten billion people, and let's get it clean, cheap, and continually available. If there's an answer, it will be some manipulation of matter on the nanoscale that will give it to us—something I like to call nanotechnology.