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Here comes the sun: the promise of solar energy

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Bringing Solar Power Down to Earth: A Dialogue

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One day the Earth and the Sun engaged in a dialogue. It went something like this:

Sun: Planet Earth, I have been observing you lately, and it looks like you are absorbing more of my energy than you have in the past.

Earth: What you see is probably the effects of CO_2, or carbon dioxide gas, released by machines built by Earthlings in order for civilization to progress forward. For example, about 40 percent of all that CO_2 comes from the burning of my coal, mostly to make electricity. In the next 24 years, Earthlings plan to build enough power plants to supply 1,350 gigawatts of power. That will release about another 572 billion tons of CO_2—more CO_2 than was released by all the coal burned in the last 250 years (Goodell, 2006). Achieving economic growth means even more CO_2 release can be expected. For example, the American type of Earthling house uses enough electricity to require 73 pounds of coal per day and produce 256 pounds of CO_2. (Shaw, 2006)

Sun: But I thought your people decided CO_2 was detrimental to the planet? If the substance powering their progress is killing you, their home, and their planet, they seem to be going backward, not forward. Besides, people already have power. I shine 170,000 terawatts on your planet every day. (The prefix *tera-* means a 1 with 12 zeros after it)! This is far more than the needs of your entire planet, which used about 13 terawatts in 2005. (de Winter and Swenson, 2006) Why aren't the Earthlings using my power, the power of the sun, to make electricity?

Earth: Well, Sun, it's complicated. The Earthlings are actually very bright, if you'll pardon the pun. They understand that emissions are harming me. My climate has been stable for more than 11,600 years, about the time we think human civilization began. The CO_2 in my atmosphere has been around 280 parts per million, and began to rise with the Industrial Revolution in the late 1800s (Shaw, 2006). The Industrial Revolution transformed a manual labor-supported economy into a machinery-supported economy. Some Earthlings have predicted that before 2050, CO_2 levels will reach 500 parts per million again. The last time that happened was 55 million to 36 million years ago. North America had palm trees and crocodiles lived in the Arctic. Antarctica was a forest and sea level was 328 feet higher than today (Shaw, 2006).

In order to prevent catastrophic climate change, Earthlings negotiated the Kyoto Protocol in Kyoto, Japan, in December 1997. The Kyoto Protocol is an agreement made under the United Nations Framework Convention on Climate Change (UNFCCC). Countries that ratify this protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases. As of April 2006, a total of 163 countries have ratified the agreement. Exceptions include the United States and Australia. Other countries, such as India and China, that have ratified the protocol, are not required to reduce carbon emissions under the present agreement (wikipedia.com).

Sun: Earth, you are confusing me. Earthlings are predicting catastrophic climate change if CO_2 levels don't drop, and they have agreed to reduce these emissions. Yet they are planning to build many more coal-fired power plants that will increase CO_2 emissions faster than before! Again, I say the people already have power. Why are they not using my solar power?

Earth: It is unreasonable to expect the Earthlings to decrease their economic growth, so they are developing and testing sophisticated technologies to capture the CO_2. For example, using a process called *integrated gasification combined cycle* (IGCC), coal can be chemically reacted to make syngas, which is a mixture of hydrogen and carbon monoxide. The syngas is used to make electricity and almost all the CO_2 can be captured, and then pumped underground; this is called

land-based sequestration. Alternatively, some Earthlings think that the CO_2 can be transported to tanker ships that will deliver it to offshore platforms, where it will be injected into the sediments at the bottom of the ocean to dissolve. It's like making seltzer seawater. It is estimated that there is enough coastline in the United States to hold enough CO_2 emissions for thousands of years (Shaw, 2006).

Sun: Still confused . . . Okay. First you spent decades engineering the technology to make electricity along with catastrophic amounts of CO_2. Now, you are beginning to engineer expensive and elaborate technologies to remove the CO_2. Why make the CO_2 in the first place? I say again, the people have the power. Solar power. You can make electricity from sunlight. The process is called the *photovoltaic effect* (photo=light and voltaic=electricity). The intelligent Earthlings have known about photovolatics for a very long time. Why do you keep ignoring my questions about solar power? Why do your Earthlings keep ignoring solar power?

Earth: Rest assured, Sun. The solar "revolution" is evolving. The intelligent Earthlings began discovering and understanding the photovoltaic effect in the 1860s. Willoughby Smith discovered that the conductivity of selenium could be altered by shining light on it. Charles Fritts built the world's first photovoltaic, or "solar," cell from the same material around 1885. This is only three years after Thomas Edison built the first coal-fired power plant. It's also not much later than when the first oil well was drilled in Pennsylvania by Edwin Drake in 1859 (Perlin, 2002).

Sun: 1885 is a long time ago. Why isn't solar power more prevalent today? Your Earth consumed 13 terrawatts of power in 2005. That's less than one-hundredth of one percent of the 170,000 terrawatts of energy that I shine on your planet every year. More than you need. You have been wasting a lot of "free" energy, and you still are.

Earth: This time has been not wasted. The Earthlings have been evolving slowly, but steadily, to get to the point where they can use your power. For the next 40 or so years after the first solar cell was built, another revolution taught the Earthlings about light energy and atoms. This could be called the quantum revolution. For example, physicist Albert Einstein helped discover that light, including light from you, Sun, is made up of packets of energy. These packets are called photons, and they come in all sorts of sizes. The amount of energy in a photon depends on its wavelength—the smaller the wavelength, the more energy.

This quantum revolution helped us learn how these photons interact with the electrons in various materials. Einstein also discovered the photoelectric effect that happens when photons of sufficient energy knock electrons loose from materials such as selenium. He won the Nobel Prize in 1921 for this effort. This contribution was especially significant because it was a first step in learning how to use materials to make electricity.

For about another four decades, the semiconductor further helped the Earthlings evolve. John Bardeen, Walter Brattain, and William Shockley discovered the *transistor effect* and developed the first device in December 1947, while the three were members of the technical staff at Bell Laboratories in Murray Hill, NJ. They won the Nobel Prize in physics in 1956.

During the 1950s, Calvin Fuller, Daryl Chapin, and Gerald Pearson, also three scientists at Bell Laboratories, invented the first silicon solar cell. The silicon transistor is the principal electronic component used in all computers, mp3 players, cell phones, and the like. Silicon is a semiconductor—a material that allows electrons to flow only moderately well. (Materials such as copper are called conductors because they conduct electricity very well). Fuller was a chemist and he learned how to introduce very small amounts of impurities into the silicon, thus transforming it into a good conductor of electricity (Perlin, 2002). This type of silicon is called "doped" silicon. There is negatively doped silicon (n-type) that has extra electrons. Positively doped silicon (p-type) has extra positive charges. A solar cell is a sandwich of p-type silicon and n-type silicon. This is the simplest type of modern electronic device based on semiconductors. When this silicon material absorbs light, it knocks electrons loose. When wire contacts are attached to the silicon device, electricity flows.

Sun: Of course. I remember on April 25, 1954, the Bell solar battery that was unveiled to the public. A panel of solar cells relying solely on my power was used to run a toy 21-inch Ferris wheel. An article from the April 26, 1954 edition of the *New York Times* stated that the solar cell of Chapin, Fuller, and Pearson "may mark the beginning of a new era . . .leading to the harnessing of the almost limitless energy of the sun for the uses of civilization" (Perlin, 2002). That was a long time ago,

Earth. Why aren't the Earthlings using more of my solar power to fuel their economic growth? Obviously, the people now really have the power.

Earth: Well, the Earthlings had to evolve even further. The age of the space race followed along with the first application for solar cells. The first satellite with solar cells aboard to help power it went into orbit on St. Patrick's Day in 1958. By 1972, more than 1,000 American and Soviet spacecraft relied on solar power. (Perlin, 2002) Following this space race came the computer revolution which began in the late 1950's and continues today. This revolution required people to learn how to make the silicon they will eventually need for solar cells. As I said before, solar cells are made from the same type of silicon used to make the electronic components of computers. While computer electronics require ever smaller pieces of silicon, solar cells require large pieces of silicon. This is because the amount of power a solar cell can generate scales with its size. A typical solar cell is currently 16 square inches.

Sun: Hmmm . . . A 16 square-inch square, you say? That means I shine about 10 W of energy on each solar cell at sea level when I am shining straight down through a dry, clean atmosphere.

Earth: Yes, that occurs at the Sahara Desert at high noon, when you are directly overhead.

Sun: I still shine light even on a cloudy day, just not as much. Typical sunlight conditions are probably closer to shining 8 W of energy on one of your solar cells.

Earth: Yes, but solar cells are only 15-20 percent efficient. That means that only 15-20 percent of the light you shine on them is converted into power (Komp, 2002).

Sun: I would argue that efficiency is irrelevant when it comes to solar cells. I emit those photons whether or not the Earthlings use them. But, even assuming a 10 percent solar cell efficiency, which is low, it would only require about 85 square miles of solar cells to power the entire United States! Conservatively, the initial outlay to solar power the U.S. would be approximately $9 billion dollars a year for the lifetime of the solar cells. This cost assumes solar power is $10 per watt. In some places, it is as low as $3 per watt (solarpowergeneration.com).

This initial cost must be less than the retail costs of all fossil fuels, their transportation and manufacturing, costs for drilling, environmental clean-ups, such as CO_2 abatement, and health costs related to illnesses attributed to fossil fuels (solarpowergeneration.com). But, since the Earthlings have discovered how to capture this energy, 15 percent or higher, why not just make more of these silicon solar cells? The people have the power.

Earth: Actually, the Earthlings have been making tremendous amounts of silicon solar cells. The solar power industry has been growing at more than 30 percent each year for the last six years! In just two years, it will use more silicon than semiconductor electronics. There is not enough silicon to meet the global demand for solar cells. This has caused silicon prices to more than double, and has slashed growth for the industry to a mere projected 6% in 2006 (Carey, 2006).

Silicon does not naturally occur in my crust. The ultrapure silicon that is needed must be made by chemically reacting sand. Sand is mostly silicon dioxide (SiO_2), which is a silicon atom chemically bonded to two oxygen atoms. The silicon we are talking about for electronic devices and solar cells consists of pure silicon atoms.

Sun: I'll say it again. The people have the power. Your crust, Earth, is rich with sand. Not to mention the moon and Mars. Why not make more silicon?

Earth: The Earthlings have begun to make more silicon. Michigan-based Hemlock Semiconductor Corporation began a $400 million expansion that will increase silicon production by 50 percent. A Munich, Germany-based company also has started construction on a silicon plant in January 2006. Government subsidies and incentives are helping to afford this increased silicon production in such a short time (Carey, 2006).

Sun: All this will help lower the costs of solar power, a new and modern goal. After all, oil and coal are only seemingly less expensive because they have decades of subsidies behind them. This should now become history. Oil gushers yielded profit over 100 years ago. Now it is time for solar (as well as wind, geothermal, and hydroelectric) to provide the better return on investment. The solar revolution also brings a whole new set of jobs for people. This is wonderful! Why not subsidize even more? Even faster? The people have the power.

Earth: There is enormous and growing activity all over my planet related to policies designed to make solar power more affordable. For example, a federal tax credit was initiated in the United States on January 1, 2006 for 30 percent of the cost of solar systems up to $2000. Many states have similar programs, such as the state of New Mexico, which has introduced a 30 percent solar tax credit up to $9000. The New Jersey Board of Public Utilities has developed one of the most progressive solar programs in the United States. It is a combination of rebates, low interest loans, and net metering (the utility will buy back extra solar energy that you generate). China has set a goal of providing 10 percent of its electricity using renewable sources (sun, wind) by 2020. But we still also subsidize the fossil-fuel industries, such as coal-fired power plants.

Sun: Now I am getting confused again. Your Earthlings are still trying to lower the cost of making CO_2 emissions?

Earth: It would be unreasonable to expect them to outright stop making electricity the old fashioned way. They still need power for economic growth.

Sun: But, they have the power of the sun. The sun can power their homes, schools, and places of work.

Earth: Many Earthlings use the sun to power their homes. It's not much more difficult than slapping some solar cells on a roof. Ideally, home solar systems should be able to track the sun. Batteries are needed to provide power when you are not shining. Otherwise, a home can still be connected to the local utility grid; but they only rely on it part of the time. Home solar systems also need an inverter; this converts the direct current (DC) from the solar cell to the alternating current (AC) that appliances need.

In many parts of the world, if you make more electricity than you need, you can sell it back to the local power company! Another wonderful thing about solar cells is that they last about 30 years. It is also predicted that homes with solar power systems will have increasing resale values. In fact, installing a home solar power system may become a significant remodeling investment in the future. In some Japanese neighborhoods, it is difficult to find a home without solar panels on the rooftop.

We have also begun to teach our children about solar energy. The fifth, eight, and tenth graders at Crested Butte Community School in Colorado helped install their own solar array at their school, which provides 1 percent of their power. Nappa Valley College uses a solar power system to supply 40 percent of the campus' electrical needs.

The Nevada Solar One project broke ground on February 11, 2006. This is a 300-acre facility that will use solar heated water to generate 64 megawatts of electricity; it is the third largest solar project in the world. The world's largest solar photovoltaic power plant is being built in Serpa, Portugal and will provide 11 megawatts of power (DeVico, 2006).

Sun: Can your Earthlings do something besides roof-mounted solar panels? They must have the power.

Earth: Oh yes. Solar architecture can be beautiful. Photovoltaic panels can be used as a reason to makeover many architecturally unappealing buildings. Numerous stylish structures designed to support solar cells can be imagined. In fact, solar cells are being incorporated into some building façade materials.

Sun: Well, it seems like the Earthlings know how to harness the sun to power their places of dwelling. Have they learned how to use the sun for transportation?

Earth: Of course. They are developing solar powered cars and planes. Big automobile manufacturers see opportunity in vehicle integrated photovoltaic applications (VIPV). This means that solar cells are built directly into the vehicle; you don't have to plug into a solar powered charging station. The solar panels may be integrated into the body panels of the vehicles in the future. Ford Motor Company introduced the Reflex—a combined diesel and electric concept car with VIPV—at the 2006 North American International Auto Show. Mazda also has developed a hybrid electric car with a rooftop photovoltaic system (Letendre, Perez, and Herig, 2006).

University students have helped contribute to the advances in solar vehicles by participating in the American Solar Challenge. This is a 2000-mile race for teams all around the world using vehicles powered only by the sun.

Solar powered flight may become reality some day. Glider pilot champion Eric Raymond has designed a plane with solar cells incorporated into the wings. He plans to fly his plane from California to Texas in the summer of 2006.

Sun: It is apparent that the Earthlings are in the process of seizing the opportunities afforded by the sun, and that fossil fuels will become an antiquated technology. The sun is stable and secure. Solar energy is distributed globally. Solar technologies can be shared and thereby bring power and knowledge to the entire world. Solar energy is "wireless"—it can power the most remote locations. Solar energy will bring more affluence to the whole world: the sun is free. Solar power is pollution free; this promises a healthier environment and population. I see that Earthlings are steadily evolving toward using the sun as a main source of power.

We've talked enough, Earth. Now, I am going to go listen to some music.

Earth: What kind of music?

Sun: A Beatles's song called, "Here Comes the Sun." It goes like this:

"Here comes the sun.
Here comes the sun.
And I say, 'It's all right'."

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