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ONLINE EXCLUSIVES

The Possibility of a Solar-Powered Nation: Nitty-gritty

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by Shaker Muasher

Q: *Given an appropriate location, how large a solar array would it take to power the entire United States, assuming present efficiency levels? How much CO2 would be released to the atmosphere in producing those panels? What other harmful byproducts would be produced, and how much?*

Asked by Paul Hayne, '03, MS '05, Los Angeles, Calif.

Different types of photovoltaic panels

A photovoltaic (PV) panel is a solar panel that directly converts sunlight (photons) into electricity (volts), hence the term "photovoltaic." There are two main types of PV cells: silicon-based cells and thin-film cells, which are mainly made of either copper indium gallium (di)selenide (CIGS) or cadmium telluride (CdTe). No matter what the specific starting materials, the idea is to use the energy of the sun to energize or "excite" electrons in the panel, channeling them into an electrical current.

Mining silicon to make silicon-based cells is an expensive process that emits a lot of carbon dioxide. Silicon-based panels are well established in the market, but are rapidly being replaced by more efficient thin-film technologies.

In general, silicon is less cost effective, but the panels are more space efficient. Therefore,

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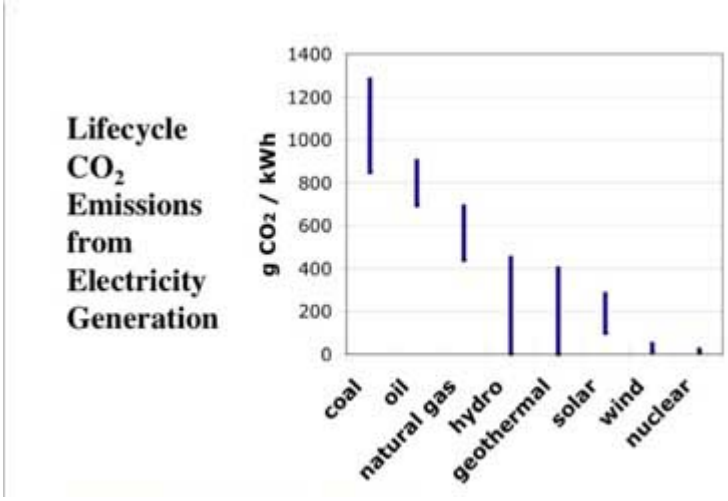
But how do these technologies, and others, differ in their environmental effects?

Environmental impacts

Below is a graph showing the CO2 emissions of solar power relative to other sources of energy. While they are lower than most other sources, solar power's CO2 emissions are greater than the CO2 emissions generated by wind and nuclear power. This is mainly due to the process of mining the silicon. Thin-film solar panels therefore generate fewer lifetime CO2 emissions than silicon-based solar panels, so as thin films gain popularity, the average CO2 emissions generated by solar power will likely drop too.



Graph: Adapted from CO2 emission from Geothermal Plants, International Geothermal Conference, Reykjavik, September 2003 (Halldor Armannsson)

Toxic chemicals

Many chemicals are used to make different types of photovoltaic cells. Here are some of the most common chemicals associated with solar panel manufacturing and their impacts.

Crystalline silicon (c-Si)

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semiconductor properties that make it so valuable for PV cells and for computer chips, too.

Sawing c-Si into the thin wafers used in panels creates a significant amount of waste silicon dust, up to 50 percent of which is lost in the air and water used to rinse the wafers. The process of making crystalline silicon from silicon is also inefficient; as much as 80 percent of the raw silicon is lost in the process.

The manufacturing process also releases silicon tetrachloride, an extremely toxic substance that reacts violently with water, causes skin burns, and is a respiratory, skin and eye irritant. And then there's sulfur hexafluoride—an extremely potent greenhouse gas, 23,000 times worse than CO2—which is used to clean the reactors used in silicon production. In developed countries, these extreme molecules are usually captured and reused in a closed-loop process, but that's not always the case elsewhere. There are reports from China, for example, of silicon tetrachloride pollution from new PV cell factories that are springing up in response to the global demand for solar electricity.

Cadmium telluride (CdTe) thin film

Cadmium is a toxic, cancer-causing heavy metal. It's nasty stuff, but expensive, too—and that means double the incentives to keep it under control and out of the air and water. Cadmium rinsed away during the production of CdTe films could potentially pollute water systems, but it is generally reclaimed and reused in other steps of the thin-film manufacturing process. Still, about one percent of the cadmium used as input is disposed of as waste. And there's a risk that cadmium could be released from thin-film panels installed in homes in the event of a fire.

Copper indium selenide (CIS) and copper indium gallium (di)selenide (CIGS)

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concern is that selenium dioxide can sometimes form at high temperatures during the manufacturing of these cells. It is a dangerous air pollutant, and can pose health risks to workers.

Overall environmental effects

Burton Richter, a Nobel laureate in physics and Stanford professor emeritus, gave a presentation at Stanford in which he explained the health impacts of the different types of energy and electricity generation. The studies used in his presentation show that virtually all of the health impacts—from coughs in asthmatics to heart diseases—of solar power are lower than those of coal, lignite, oil and gas. Other studies have also supported these observations. These impacts can be lowered even further, through regulatory oversight of solar panel manufacture and disposal.

Economic feasibility

The main obstacle to large-scale commercialization of solar power boils down to economics. Currently, the solar industry can produce electricity at costs ranging from 15 to 22 cents per kilowatt-hour, but energy customers only pay 7 to 13 cents per kilowatt-hour for their energy, which largely comes from coal, petroleum and natural gas power plants. With government subsidies in states such as California and cash-back incentives for customers, renewable energy sources such as solar are becoming more popular. For example, here at Stanford, the Palo Alto Utility Company gives us students the option to purchase all our electricity from wind and solar farms for only 1 cent more per kilowatt-hour than we would pay for energy generated from conventional sources. (Solar actually costs 5 cents more per kilowatt-hour to produce.) My roommate and I went straight for it.

Researchers predict that the solar industry will eventually reduce its cost of producing electricity down to 10 cents per kilowatt-hour. Some companies and independent

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Bottom line

The environmental impacts of solar power will depend, first and foremost, on solar panel manufacturing practices. Proper regulatory policies to ensure the safe manufacture and disposal of solar panels will further reduce the already minimal environmental impacts of solar power.

The U.S Occupational Safety and Health Administration (OSHA) has already set policies to safeguard employees in solar panel manufacturing factories. The Obama administration is taking steps to further improve the renewable energy industry, with a focus on economic viability, sustainability and environmental responsibility. Such steps could help solar power's benefits shine bright, and in time, give way for a grand plan for solar energy.

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