The Promise Of Solar Energy: A Low-Carbon Energy Strategy For The 21st Century

In an increasingly carbon-constrained world, solar energy technologies represent one of the least carbon-intensive means of electricity generation. Solar power produces no emissions during generation itself, and life-cycle assessments clearly demonstrate that it has a smaller carbon footprint from "cradle-to-grave" than fossil fuels.

Of the more than 10,000 terawatt-hours (TWh) of electricity generation produced by the countries of the Organization for Economic Cooperation and Development (OECD), solar currently accounts for just 8 TWh. Yet solar technologies, including photovoltaics, concentrating solar power and solar thermal constitute the fastest growing energy source in the world. With clear market signals from Governments, these low-carbon technologies could provide more than 30 per cent of the world's energy supply in aggregate by 2040.

Photovoltaics (PV) are perhaps the most well-known and fastest growing sector of solar technology. PV devices generate electricity directly from sunlight via an electric process that occurs naturally in certain types of material. Groups of PV cells are configured into modules and arrays, which can be used to power any number of electrical loads. PV energy systems have very good potential as a low-carbon energy supply technology. A September 2006 joint paper by scientists from Brookhaven National Laboratory, Utrecht University and the Energy Research Center of the Netherlands demonstrates that crystalline silicon PV systems have energy payback times of 1.5 to 2 years for South European locations and 2.7 to 3.5 years for middle-European, while thin film technologies have energy payback times in the range of 1 to 1.5 years in South Europe.

Accordingly, life-cycle carbon dioxide (CO2) emissions for PV are now in the range of 25 to 32 g/kWh. In comparison, a combined-cycle gas-fired power plant emits some 400 g/kWh, while a coal-fired power plant with carbon capture and storage, about 200 g/kWh. Nuclear power emits 25 g/kWh on average in the United States; only wind power is better with a mere 11 g/kWh. For silicon technology, clear prospects for a reduction of energy input exist, and an energy payback of one year may be possible within a few years as silicon growth processes become more efficient. As a result, this could decrease the life-cycle CO2 emissions to 15 g/kWh.
The global photovoltaic sector has been growing at an average of over 40 per cent in the last eight years, manufacturing over 2,200 megawatts in 2006. PV have become competitive in all market segments, particularly grid-connected applications, as more investment in the sector has produced major advances in automation, manufacturing efficiencies and throughput. Several leading countries – Germany, Japan and the United States, representing two thirds of the global market – have provided market support programmes to drive down costs. The growth of PV has driven a very classic "experience curve" decline in manufacturing prices. Data fairly clearly demonstrate an 18 to 20 per cent "progress ratio" – for every doubling in the cumulative production of solar cells, prices come down about one fifth. Currently, solar modules are selling globally from $3 to $5 per watt, while installed systems are generally sold at between $6 and $10 per watt. Solar energy is the cheapest option for providing power to locations more than half a mile from existing electricity and is generally competitive without subsidies in regions with high energy prices. The PV industry is striving to reduce system costs by 50 per cent by 2015, at which point PV will be cost-competitive with retail electricity costs in most of the United States and other developed countries.
As PV technology becomes increasingly affordable and available, its potential as a major source of low-carbon energy grows. In a 2004 report entitled Solar Generation, Greenpeace and the European Photovoltaic Industry Association (EPIA) estimated that, by 2020, PV could provide 276 TWh of energy – equivalent to 1 per cent of the global demand projected by the International Energy Agency (IEA). The study assumed that the PV market would grow at a compound annual growth rate of 30 per cent until 2020, well below the 45-per cent growth that the industry averaged from 2002 to 2007. This would replace the output of 75 new coal-fired power stations and prevent the emission of 664 million tons of CO2 annually. Moreover, the report found that with a 15-per cent growth rate from 2020 to 2040, the solar output could be more than 9,000 TWh, which would be 26 per cent of the projected global demand.
Concentrating solar power (CSP) plants are utility-scale generators that produce electricity by using mirrors or lenses to efficiently concentrate the sun's energy. Two principal CSP technologies are parabolic troughs, which use rows of curved mirrors to drive conventional steam turbines; and the dish-Stirling engine systems, which are shaped much like large satellite dishes and covered with curved mirrors that heat liquid hydrogen to drive the pistons of a Stirling engine. Life-cycle assessment of the emissions produced, together with the land surface impacts of CSP systems, show that they are ideally suited to reduce greenhouse gases (GHG) and other pollutants, without creating other environmental risks or contamination. According to the European Solar Thermal Industry Association, 1 MWh of installed solar thermal power capacity results in the saving of 600 kilograms of CO2. The energy payback time of CSP systems is approximately five months, which compares very favourably with their lifespan of 25 to 30 years.
During the 1980s and early 1990s, developers built nine concentrating solar power plants in California's Mojave Desert for a total of 330 MW. Then, for nearly two decades no new plants were built due to the weakening of the United States federal support for renewables and plummeting energy prices. However, CSP has experienced a renaissance in the last two years. An 11-MW plant in Spain – the first in Europe – became operational in March 2007, while a 64-MW plant in Nevada is in its final stages of construction. Currently, over 45 CSP projects worldwide are in the planning stages, with a combined capacity of 5,500 MW.
With more than 200 GW of resource potential in the American southwest and thousands more throughout the world, CSP offers a rapidly scalable means of low-carbon electricity generation. A September 2005 report by the European Solar Thermal Industry Federation (ESTIF), Greenpeace and the IEA SolarPACES found that "there are no technical, economic or resource barriers to supplying 5 per cent of the world's projected electricity needs from solar thermal power by 2040". The authors calculated that CSP could produce 95.8 TWh/year by 2025, avoiding 57.5 millions tons of CO2 annually for a cumulative 362 million tons in the next 20 years. By 2040, they found that CSP could produce as much as 16,000 TWh per year.
Solar thermal systems provide environmentally friendly heat for household water and space heating. Simple collectors, usually placed on the roof of a house or building, absorb the sun's energy and transfer the heat. In many climates, a solar heating system can provide a very high percentage (50 to 75 per cent) of domestic hot water energy. Since, on average, water heating accounts for around 30 per cent of a home's CO2 emissions, a solar water heater can reduce its total emissions by more than 20 per cent. Many countries are encouraging increased use of solar hot water technology. Worldwide, installations grew 14 per cent in 2005 to an installed base of 88 GW thermal equivalent, with 46 million houses equipped with the systems. China leads the way, with 62 per cent of the installed capacity, while Israel has the highest per-capita usage, with 90 per cent of all homes taking advantage of the technology. The IEA Heating and Cooling Program in April 2007 calculated that this global installed solar thermal capacity reduces CO2 emissions by approximately 30 million tons each year. In January, ESTIF proposed an ambitious target of installing 1 square metre of collector area by 2020 for every European – 320 TWh of installed capacity. Meanwhile, in March, the United States National Renewable Energy Laboratory calculated the current technical potential of solar water heating in the United States at 1 quad of primary energy savings per year, equivalent to an annual CO2 emission reduction of about 50 to 75 million metric tons.
Solar energy is an obvious choice for a carbon-smart, reliable energy future. Greater reliance on this comparatively untapped energy resource will help mitigate climate change while stimulating economies, creating jobs and increasing grid integrity and security. However, without robust international and national policy support for solar and other renewable energy sources, society will continue down the path of over-reliance on highly price-volatile, insecure and carbon-intensive energy sources. Incentives for early adopters, regulatory policies and education initiatives must all be in place to jump-start the mass-market adoption of solar energy. With clear market signals, the industry can build up low-carbon solar energy on a scale large enough to help solve our global energy challenges.

About the author

Rhone Resch

Rhone Resch is President of the Solar Energy Industries Association (SEIA), a national trade association representing over 500 solar energy companies in the United States.

Giving Life With the Sun: The Darfur Solar Cookers Project

For the 200,000 displaced citizens of Darfur living in refugee camps in Chad, the simple task of cooking a meal poses serious risks. Since wood for cooking is scarce in the desert region, refugees must travel several miles outside the camp to gather firewood, where they are highly vulnerable to attacks by the Janjaweed militia and other predators. A 2005 report by Médecins Sans Frontières found that 82 per cent of rape attacks occur when women are outside the populated villages, usually while searching for firewood. But in the Iridimi camp with 17,000 refugees in eastern Chad, families have cut their firewood use by 50 to 80 per cent, using simple solar cookers to prepare their meals.

Most solar cookers work on sunlight being converted to heat energy that is retained for cooking. While there are many successful designs, the most adaptable to the needs of refugees is CooKit, from Solar Cookers International, which is made of cardboard or other local material and is cut into a specific shape to effectively reflect the solar light rays toward a black metal pot. The pot, when painted black on the outside, absorbs and retains solar heat. A clear polypropylene bag tied around it creates an insulating barrier and allows the pot to easily reach 250? Fahrenheit (about 121? Celsius), which is more than enough to cook several litres of food in a few hours.

The KoZon Foundation, a Dutch non-governmental organization that trains women in developing countries to solar-cook, brought the devices to the Iridimi camp for the first time in February 2005, after it obtained funding from the Dutch Foundation for Refugees and a project approval from the United Nations High Commissioner for Refugees (UNHCR). KoZon volunteer, Derk Rijks, and Chadian trainee, Marie-Rose Neloum, provided 100 cookers to several women refugees for a demonstration, which proved to be a success.

A second demonstration was organized in April 2005, in which KoZon trained and tested the ability of the refugees themselves to manufacture 120 cookers, emphasizing the creation of a self-sustaining economic activity. A basic workshop, completed in February 2006, provided the necessary tools and space for the manufacture of the cookers. Several refugees were also trained as "auxiliary trainers", who would teach others how to solar-cook.

The Solar Cooker Project accelerated in May 2006, when a coalition of 55 synagogues in southern California in the United States, the Jewish World Watch (JWW), stepped in to fund the large-scale introduction of the cookers throughout the Iridimi camp. The coalition works to combat genocide and other human rights violations worldwide, and its women's committee takes on volunteer projects that particularly impact women. "The only way you fight death is by giving life, and the only way that you can overcome genocide is to ameliorate the suffering", said JWW founder, Rabbi Harold M. Schulweis. "In this case you have defenseless women without any protection, subject to the sadism of the Janjaweed. To be able to give them the smallest amount of protection and security is of primary significance."

The Project has so far trained 4,500 women and supplied 10,000 cookers to refugees. The Iridimi camp now manufactures approximately 1,000 solar cookers a month as replacements (the cookers typically last for six months), while supplying excess cookers to the 22,000 refugees in the nearby camp in Touloum. The Project has also reduced the number of foraging trips by approximately 70 per cent, thus lowering the risk of attacks on women and girls. The cookers also provide economic opportunities, not only in their direct manufacture, but also by giving refugees some free time for other activities, rather than cooking and collecting firewood. Many of the women are now engaged in basketry, knitting and other handiwork selling in Europe, by special arrangement with UNHCR and the airlines.

The Project has also reaped significant environmental benefits for the people and the region. By reducing firewood consumption, it has slowed down the deforestation process. The zero-pollution cookers have reduced smoke in the camp, consequently providing health and quality-of-life benefits for refugees. Project partners believe that with the support of the United Nations, the Project could bring solar cookers to the rest of the 200,000 refugees in Chad.

"As important as it is to alert the world, there is nothing that alerts the world more than action", said Rabbi Schulweis. "For the United Nations to adopt this would be a reinvigoration. It's illustrative of what can be done even in impoverished countries, even in countries that are divided and scared to death because of internal warfare, that at least we can shield them and give them protection. It raises the solar industry into something that has a moral character, as well as an entrepreneurial character. In this age, we need not only high technology but also high morality."- Rhone Resch and Noah Kaye

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