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Solar Energy: A Fresh Look at the Sun

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Abstract. This paper was my attempt to give solar energy a voice in the midst of discussion about the growing problems with global warming, fossil fuels, and bio-fuels. In reading and studying these topics, it becomes clear that with or without considering the damage fossil fuels are doing to the planet, there are many economic and political reasons to seriously consider alternative sources of energy. However, switching to new sources should be done with careful consideration of their own pros and cons. In my reading about solar energy, the pros seemed undeniable and the cons seemed surmountable. Solar energy has not received the same level of hype or government support that fossil and bio-fuels have enjoyed. The public seems to know little about solar energy – how it works, its benefits, the misconceptions about its pitfalls, and its capabilities. Fortunately, other countries such as Japan and Germany have already taken the initiative to test out policies to support solar energy and have had great results. Unfortunately, the U.S. does not seem to be moving in the same direction. This paper was written with the intent to spread the idea of free, truly green energy, not just for the future, but for the present as well.

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Society has had a mixed relationship with fossil-fuels. On one hand, the great power that it holds is both portable and easily harnessed. These two qualities have led to all the major accomplishments in technology (Bradford, 2006). On the other hand, its environmental costs are rising to a price that the Earth can not afford. There are many options for alternative energy sources to help reduce the amount of carbon dioxide that is in the atmosphere. However, one in particular has many unique benefits that may not be ignored much longer. Solar energy has long been kept in the shadow of fossil-fuels and biofuels. It is time to reexamine this technology to find if it is ignored because of problems with its design and expense or because the public knows little about what solar energy is today.

The purpose of this paper is to cover many aspects of solar energy. It will start with an introduction to types of solar energy. Discussing a few of many, many new technologies will give a look at the future of photovoltaics and show how diversely it is being researched. One important and unique material used in solar panels and its manufacture will give an idea of how far solar power's green credibility stretches. The problem of solar panels only producing energy when the sun shines will be discussed, as well as how the energy is used and stored. Some additional benefits to solar panels show more about the marketability of panels. A look into solar energy's dark past may explain its small role today. A few countries overseas have committed seriously to solar energy and have already reaped benefits, and a few on-looking oil companies have taken interest. Federal and state initiatives in the U.S. show support for photovoltaics, while the current administration contradictorily shows a lack of support. Finally, a replay of the possibilities of solar energy will lead to questioning what role it could play in the energy market, as well as a game plan for increasing awareness of this free energy to government, industry, and the consumer.

Plants may take credit for the first use of solar energy in the form of photosynthesis, but humans continually add to the number of ways they use the sun. Passive solar energy has been used for longer than documented, as it can be used as light and heat anytime the sun is out. “In passive solar design, heat and light are not converted to other forms of energy; they are simply collected. This is done through various design and building methods such as orienting a building toward the sun or including architectural features that absorb energy where it is needed and exclude it where it is not useful,” (Bradford, 2006). Some examples of this may be using daylight to see instead of turning on the lights, or opening up window coverings to let the sun warm a room.

Active solar energy is the term used to describe storing solar energy, converting it to electricity, or for heating water. Active solar energy is simply comprised of thermal and photovoltaic applications (Bradford, 2006). The first thermal solar-powered steam engine was designed in the 1860s, followed the next decade by the development of solar troughs that generate electricity. Beginning in the 1900s with Becquerel’s discovery of electrochemical applications and Einstein’s understanding of the properties of light, photovoltaic developments took past knowledge of solar energy and propelled forward with new technologies that are continuing to be developed and made more efficient today (Simon, 2007).

A few of these new technologies are being used in alliance with steel. A new kind of photovoltaic device called “nanostructured dye solar cells (DSCs)” which are deposited on stainless steel promise to replace the most expensive material in currently used solar cells. “Traditionally, DSCs are deposited on conductively coated glass sheets which account for more than 30 percent of the material cost.” These devices have also shown a relatively high efficiency.

Researchers at the Helsinki University of Technology are now studying the durability of the new steel components (Steel Forges, 2008).

Another technology involves painting solar cells onto steel. Solar cell systems can be painted on with rollers similar to regular paint. The new method would be used for cladding on buildings and boasts two impressive capabilities: being better at using the low light radiation that is found in most not-so-sunny climates and the possibility of generating the equivalent amount of electricity as 50 wind farms. This “50 wind farms” claim is based on if all 100 million square meters of steel cladding that Corus Colours produces in a year were to be covered with this new photovoltaic paint. This is an underestimate because it accounts for a lower-than-expected energy conservation rate (Colorful Ideas, 2008).

Solar cells can do more than be painted onto steel; it can also be screen-printed in many colors and designs to be used in place of windows, similar to stained-glass windows. The cells have nanoparticles and an organic dye, so they absorb most of the sun’s light while still being semi-transparent. Unfortunately, as of now they have a low efficiency, and so would only make a minor contribution to providing electricity (Screen-printed, 2008).

A truly futuristic material has been developed by Harvard chemists. It is a nanowire that is fashioned from three different kinds of silicon and yet is hundreds of times thinner than hair. What makes it amazing is that it not only transfers electricity, it also generates its own electricity. These nanowires are better than past nanowires that have been worked on because they are cheaper to produce, are 5 percent more efficient, and do not deteriorate when exposed to concentrated light. Extremely small circuits can use the nanowires, including sensors that can detect a single virus, particle, and even individual signals from individual neurons (Nanowire Generates, 2007).

As amazing as they are, these technologies are all still being researched and are far from being available on the general market. It would perhaps be more beneficial to look at already used applications, and to look at them from many angles. All of these angles will derive from either science and technology or economics.

Perhaps the most promising aspect of solar energy is the source of its power: the sun. “Every hour the sun beams onto Earth more than enough energy to satisfy global energy needs for an entire year,” (A Surging Energy Source, 2008). This is only significant, however, if that energy can be harnessed and if it can replace a significant portion of the energy created from fossil fuels. Photovoltaics are used to produce electricity, which is an increasingly important commodity. “Electricity consumes roughly one third of the primary energy used in the world….Economies depend on the quality, reliability, and quantity of electricity available to them and the efficiency with which it is used.” Over just a thirty year period starting in 1973 the demand for electricity grew faster than the basic energy demand; it increased more than 170 percent. And unsurprisingly, Coal, oil, gas, nuclear, and hydro have been, and are still, the main sources of electricity (Bradford, 2006). Solar power currently accounts for “less than one tenth of one percent of global energy demand,” (A Surging Energy Source, 2008). So how does solar power work and what is it made of?

Photovoltaic cells, which are more commonly called solar panels, are made of semiconductors. The most widely used semiconductor material is silicon, which is also used in cell phones and computer chips (A Surging Energy Source, 2008). The cells are attached to two electrodes. When light hits the cells, the energy in the light knocks electrons free from the semiconductor atoms. The electrons flow, causing an electric voltage between the electrodes, and generates electricity (Goetzberger, 2005).

Simple uses of this method that just use the cells without any battery attached include solar powered calculators, irrigation pumps, and freshwater distillers. These are examples of nonconcentrating systems. Nonconcentrating systems just allow sunlight to fall on them without using mirrors or lenses to concentrate the light. Cells can also be attached to a battery that stores excess electricity, such as systems that are used in homes. These are examples of concentrating systems (Bradford, 2006). Solar thermal plants use concentrating systems to boil water to drive a steam turbine (A Surging Energy Source, 2008).

Parabolic troughs, a very popular use, have u-shaped mirrors to concentrate light. This heats oil that runs along pipes to boil the water. They have recently been made much more efficient by simply improving ways to align the mirrors. This sounds easy enough, but people have been working on methods of aligning the mirrors that are less time-consuming for twenty years. The new method uses vector algebra, projection theory, and digital cameras (Parabolic Trough, 2007).

Solar panels use mostly the same supplies as other building projects with the exception of silicon. The most effective and costly to produce is formed from pure silicon that is sliced thinly and chemically treated. Next to oxygen, silicon is the most abundant element on the surface of the earth, but is found as silicon dioxide. Processing it into pure silicon requires a lot of energy, which accounts for fifty percent of the cost of a solar panel module. The cost has sometimes been reduced by using reject material from other semiconductor industries (telecommunications and computers). This is a problem because it made the photovoltaic industry dependent upon these other industries (Goetzberger, 2005).

It is often argued that manufacturing silicon uses toxic materials that harm the environment, and this is true. However, all the steps of the manufacturing process are run in a loop. This means the reagents used to make silicon dioxide into silicon are recycled over and over again. And thanks to the many years of the same type of manufacturing for other semiconductor industries, the loop is very tightly concealed and controlled by environmental protection standards. Photovoltaic cells are pollution free – emitting no noise, no solid waste, and no harmful gases. Much, if not all, of the materials are recyclable as well.

> The electronic and electric components of a PV system such as the inverter, batteries, charge controller, and cable can be recycled by existing and proven technologies without any problems….Installation materials (for example mounting supports or frames for façade integration of the solar modules) usually consist of metal (high-grade steel or aluminum), which can be recycled like normal scrap metal.

The process of recycling described in detail in Photovoltaic Solar Energy Generation saves almost 80% of the primary energy needed for manufacturing (Goetzberger, 2005).

It is a common complaint that solar panels only produce energy when the sun is out. This does not need to be a problem. As it turns out,

> …consumer electricity demand and the power that utilities must provide throughout a typical day neatly track the daily and seasonal energy cycle of the sun. The times of day when energy demand is the highest coincides with those when the sun shines more brightly, including part of the electricity demand that is directly tied to the sun's availability, such as summer air conditioning.

Utilities need two types of electricity: base-load electricity that is used every hour and intermediate-load electricity which is used only during certain parts of a day. Solar energy is perfect for providing this intermediate-load electricity. Intermediate-load electricity comes from generators and is more expensive to generate and, even though it is used part time, makes up 30-50 percent of electric demand (Bradford, 2006).

Solar grids are the same as regular electricity grids in that they are also able to output any range of power, from microwatts to megawatts (Goetzberger, 2005).

> Grid tied solar electricity is generated when the sun is shining, and the excess is stored by sending it back into the utility grid supply. At night, users purchase conventionally generated power from the grid as needed. The grid itself functions as a huge storage battery that is available for backup power and eliminates the need for system owners to install expensive equipment to provide storage and backup electricity services.

These are called grid-connected photovoltaic systems. This is a good option for buildings or homes that are already connected to a grid. For people who are not currently connected to a grid, photovoltaic systems would actually be the most cost-effective system to set up (Bradford, 2006).

All modern cities are powered by electricity grids. The National Academy of Engineering said the electricity grid was the greatest invention of the twentieth century. Electricity grids allow for electricity to be in a more versatile form than fossil fuel and "thanks to the sheer size of and number of people connected to the electricity infrastructure, a century of accumulated technical experience, and substantial government subsidies—retail prices for electricity are at their lowest levels ever," (Bradford, 2006).

Even though the grid may be the greatest invention of the last century, it has had one major problem: blackouts. Blackouts can cause a country billions of dollars in damages and lost business. The surface problem is that the grids are not well maintained. The underlying problem is that the government decided to deregulate the system to help lower costs. This made the utilities focus on short term profits because they had no reason “to reduce consumer energy usage or their cost structures because revenue was determined on a cost-plus basis,” (Bradford, 2006). The current electricity grids are mostly in poor shape, and so adding to or replacing them with grid-connected photovoltaic systems could be beneficial to ending major blackouts. However, government support may be needed in order to replace grids.

There are many additional benefits to using solar panels. Solar panels have no moving parts, so they require very little maintenance and have a very long lifetime (Goetzberger, 2005). Before they would need to be recycled, the average life of a panel or module is thirty plus years. “Solar panels can be serviced piecemeal, too, while the remaining panels in the array continue to make electricity uninterrupted,” (Bradford, 2006). They are also very versatile in that they can be used anywhere from out in space to an individual home (A Surging Energy Source, 2008). Solar panels also do not pose a threat towards land use. In fact, in some areas they may improve land use. “In desert areas, it is even possible to provide shading by modules that at the same time generate electricity for irrigation and desalination of water,” (Goetzberger, 2005).

With all of this amazing potential, why does solar energy play such a minor role in the United States’ energy demand? Portrayal of solar energy may be the most important reason. Fossil fuels and biofuels are heavily supported and very popular. They are said to be cheaper, easier to deploy, and implied to be more realistic. Solar energy also has a bad reputation in the minds of many people. It was promoted and invested in heavily in the 1970s during the OPEC oil shocks. The support came from fuel providers, electric utilities, environmentalists, and solar installers alike, but when the government cut off its support in 1982, solar energy nearly became extinct. The people who gave it support lost substantial amounts of money and solar energy was deemed incapable of surviving without substantial government subsidies. In a recent poll, 90 percent of people in the United States want solar energy to be a solution (Bradford, 2006). The desire is there if solar energy could only be allowed to be proven effective and able to quickly be independent of the government's support.

Even though solar energy is an underdog in the United States' energy market, it has found much success elsewhere, especially in Japan and Germany. They have concentrated on supporting grid-tied residential photovoltaics.

> Although these two countries do not have a naturally high amount of sunlight, their lack of alternative fuel sources has created a dependence on expensive external sources of energy… Japan's sunshine program and Germany's 100,000 solar roofs program, which have used various types of subsidies to stimulate robust domestic solar energy industries, now account for 69 percent of the world market for PV (Bradford, 2006).

Japan's residential PV-dissemination program was implemented in 1996 and has since lowered the cost of installation by half. The subsidy was reduced from covering 50 percent of the system price to just 7 percent and yet demand still increased greatly. This signaled "a belief by homeowners that the solution is now nearly at parity with retail electricity rates." Germany's performance-based incentives instituted in 1999 have increased photovoltaic growth 150 percent in 2005. Germany's lead in photovoltaics in Europe is expected to decrease as other countries follow suit and increase their use of solar energy. And in Europe, "supply is not projected to keep up with demand because many manufacturers have already committed over a year's worth of production to customers," (Bradford, 2006). One thing Japan and Germany have learned is that green energy or no, it is hard to ignore the economics of solar energy. In 2005, solar energy stock market initial public offerings created billions in global wealth (Bradford, 2006).

Photovoltaics are already a multibillion dollar industry (Bradford, 2006.) The world market in 2002 for photovoltaics was at a value of about $1 billion. “Market growth in the last decade was between 15 and 25% per year and has risen recently to 30% and even 40%,” (Goetzberger, 2005). This growth increase lowered the cost of production of photovoltaic systems from $11 per watt to $5 per watt and is continuing to drop. Projections estimate a continued 20-30 percent growth every year for the next forty years (Bradford, 2006.)

With growth, photovoltaics will become cheaper. This affects more than just electricity used in homes, but could also encourage the transition to electric- and hydrogen-powered vehicles. It could also “reduce the cost of drinking water through desalination and provide cheaper water and fertilizer for agriculture,” (Bradford, 2006).

If implementing solar panels seems expensive, it is easily counterbalanced by its energy payback time. Energy payback time is unique to renewable resources and is described as the operational time required for the source to make up for the energy consumed during its production. This varies for the different types of silicon crystals and technologies used, but peaks at about seven years. The lifetime of most is over 25 years (Goetzberger, 2005). “The useful lifetime of a photovoltaic cell is a function of manufacturing methods and the atomic stability of the substrate material, but some PV cells have been in operation for decades in space-based satellite applications, one of the harshest possible environments,” (Bradford, 2006).

From 1989 to 2003, independent power producers in the U.S. had a 67 percent growth increase in solar use (Simon, 2007). Even oil companies are finding solar energy hard to ignore and hard to resist. One of the larges oil companies in the world – Shell Oil Company (or Royal Dutch Shell) – has published a study that predicts photovoltaics will account for a large portion of energy production (Goetzberger, 2005). “America’s PV production is dominated by these two oil-company owned solar divisions (referring to BP Solar and Shell Solar), and General Electric entered the fray in 2004 by purchasing America's largest independent PV producer, Astropower, out of bankruptcy," (Bradford, 2006).

The costs of photovoltaics do not fluctuate with the costs of replacing equipment and power plants because "governments often take on some of the costs of building, financing, and protecting the energy business and pass on those costs to consumers in the form of taxation rather than in the cost of delivered power," (Bradford, 2006). So how is the United States supporting solar energy as a serious energy contributor?

The leading federal program is the Solar Energy Technology Program, or SETP. One of their top priorities is improving the cost of solar energy to make it more competitive. It has seen that the cost is declining but will remain slightly higher or equivalent to fossil fuels for the rest of the decade. It offers grant opportunities to universities and private industries for research. Resources and financial incentives are offered to homeowners, private industries, utilities, and government organizations. Another major accomplishment is the Million Solar Roofs Incentive. "The Million Solar Roofs Incentive counts 350,000 solar roof installations since 1997 toward its goal of 1 million installations by 2010," (Simon, 2007).

However, this does not seem like very much, and support is actually dwindling. The Solar Energy Technology Program (SETP) had only a 2 percent increase from $83.4 million in 2004, but such a small increase is actually considered a step back in spending power (Simon, 2007). For 2008, President Bush's funding through the program on energy efficiency and renewable energy for solar energy will see a 7 percent $12 million decrease. At the same time, funding for fossil fuel research such as carbon capture and storage will be increased 21 percent, and a 40 percent increase in nuclear energy research. Clearly, solar energy is not a priority in the executive branch (Schoof, 2008).

The senate has had a more positive influence. From the first of 2005 until the end of this year there is a 30 percent solar energy investment tax credit for both businesses and homeowners. After this year it was to be reduced to 10 percent indefinitely, but this month, April of 2008, the senate voted 88-8 in favor of extending the tax credit through the Housing Stimulus Act of 2008 another eight years. There is no cap for the business credit, and a $2,000 cap per solar technology system for the residential credit. For homeowners this included photovoltaics and solar domestic water heating. For businesses the range is slightly wider, adding concentrated solar power (CSP) and solar hybrid lighting. However, the tax credits are not for systems that were installed before 2005 (SEIA, 2008).

States are also taking an active roll in supporting solar energy. California is the leading state in solar systems purchased. It “offers Supplemental Energy payments (SEPs) to alternative/renewable energy producers who receive below market prices for energy sales to utilities,” (Simon, 2007). It has dedicated $400 million to its New Solar Homes Partnership (Go Solar California, 2008). The Million Solar Roofs Initiative includes $2.9 billion in solar incentives for home and building owners. Governor Arnold Schwarzenegger says, “My Million Solar Roofs Plan will provide 3,000 megawatts of additional clean energy and reduce the output of greenhouse gasses by 3 million tons which is like taking one million cars off the road,” (State of California, 2007).

One rural, high poverty county in Washington “has offered 0 percent interest loans to individuals purchasing and installing solar energy systems for their homes,” (Simon, 2007). The County of Maui in Hawaii has done likewise, with interest free loans for the installation of solar water heating in homes. Honolulu’s Solar Roofs Loan Program offers 0 to 2 percent interest on loans to low-income homeowners to install solar water heating systems (DSIRE, 2008). Nevada is building a 64 megawatt Nevada Solar One power plant, the largest solar thermal power plant built in 15 years, in Boulder City. It will support the needs of about 40,000 homes. A similar 354 megawatt solar thermal power plant is in California’s Mojave Desert, but the one in Nevada has newer technologies to better capture energy (Butler, 2006). Incentive for every state can be found on the Database of State Incentives for Renewables & Efficiency (DSIRE) website.

Nebraska has almost identical corporate and personal Renewable Energy Tax Credits. The tax credits cover solar thermal electric and photovoltaic systems as well as other technologies. The credit amount changes with time and is set to end in 2017. The current amount is $0.001 per kilowatt hour until the end of 2009, lowering to $0.00075 per kilowatt hour until the end of 2012, and finally $0.0005 per kilowatt hour until the end of 2017 (DSIRE, 2008).

Nebraska’s Dollar and Energy Savings Loans program was started in 1990 using oil overcharge funds. “As of Feb. 2007, 23,689 individual loans had been made totaling $190.3 million.” Eligible technologies focus on efficiency and renewablity, and include solar water heat, solar space heat, solar thermal electric, and photovoltaic technologies. Interest rates are 5 percent or less. Many different sectors can apply, including commercial, residential, nonprofit, local government, multi-family residential, and agricultural. “Maximum payback term is ten years for home, building and system improvements, five years for appliance replacements and the simple payback period for projects requiring an audit.” The maximum amounts available range from $35,000-$75,000 for residential loans to $75,000-$175,000 for non-residential loans (DSIRE, 2008).

Other countries such as Japan and Germany have seen that by giving solar energy a solid start, such as implementing subsidies, it does not take long for photovoltaics to become more competitive, and in turn, become cheaper without the government's support. The U.S. has also started to follow suit and has seen similar impacts. It is difficult to tell how soon – or if – solar energy will go from one-tenth of one percent of the world's energy demand to thirty percent (or one hundred percent of electricity demand), but it certainly seems to be a possibility.

The concept of solar energy is very attractive because it means using truly free energy. The quantity of it is only regulated by the spinning of the earth and the placement of the clouds. It emits no form of pollution, no sound, no chemicals. The materials used to build solar panels can be recycled, as well as the chemicals and used to make the silicon. It seems as if solar energy may be the greenest form of energy available.

One big question is how big of role can solar energy possibly play? Could it replace all of our electricity needs? With the improvements that have been made and that will continue to be made and the new ways that solar panels can be incorporated into the buildings and electronic devices around us, this is a very major possibility. This impact alone would be an incredible step towards reducing carbon dioxide emissions and global climate change. Could it replace the fuel used in transportation? This is a more difficult question. As the cost of photovoltaics decreases and solar power begins to supply our electricity needs, electric- and hydrogen-powered vehicles may share a similar interest from the public and support from the government. As for using solar energy itself as fuel, a group of chemists at Yale are working to do just that. Supported by the Department of Energy, the team has received $12.8 million to find a way to use "photocatalytic cells for water cleavage with visible-light power," (Yale Chemists, 2007). However, it is unclear what the byproducts would be from the chemicals used to produce the fuel and it is even more unclear how long it will be until they have successfully completed this research. An interesting question is if solar energy could be made to replace fossil fuels for electricity generation, how would fossil fuel prices be affected? An equally interesting question is if the world were able to have as much solar-generated electricity as it wanted without pollution or worries of exhausting its source, how far could technological advances go?

For solar power to reach its full potential, it should be marketed in two different approaches, both aimed towards government and industry and towards consumers. Both groups are concerned with cost and environmental issues. Focusing first on involvement of the government and industries will allow for the market to grow and for photovoltaics to become more affordable to more people. For the government and industries to sit up and take notice they must be shown the economic potentials of solar energy. “The rapidly maturing solar-power industry needs to transform the discussion from one based on environmental doomsday scenarios to one focused on the wealth that can be generated by accelerating the shift to solar energy. Greed trumps fear, which early movers in Germany and Japan are already learning as billions of dollars of global wealth are created through stock market initial public offerings (IPO’s) in 2005 alone,” (Bradford, 2006). Although most people agree that solar energy is a highly desirable solution, they may still believe there are major problems with it. “Full understanding of the increasingly seamless technological interface of solar energy systems and residential and commercial energy demand may not be understood by potential consumers,” (Simon, 2007). The change to solar energy itself also has the potential to be seamless, as it should not be much different from the change from land-line communications to mobile communications (Bradford, 2006). Its effects on the earth are desirable, the technology is available and continuously improving, and it is no longer an unavoidable economic underdog.

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