Spotlight on Tomorrow's Photovoltaics

Exploit the abundant power of the sun

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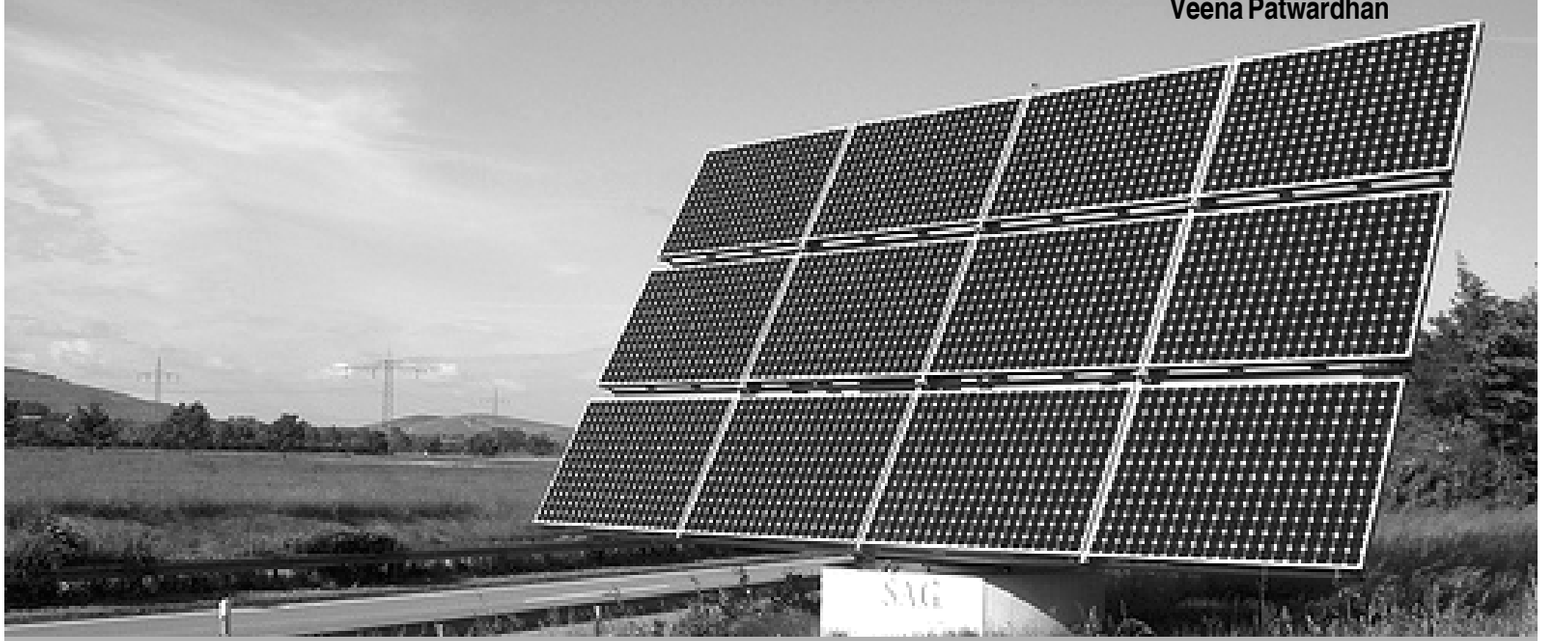

Looking at the environmental damage brought about by industrial development, and the energy crises across the world, it seems like the only way forward would be through the use of a clean, renewable source of energy such as solar power. From once being used in spacecrafts and for charging small solar panels in calculators and watches, solar energy has come a long way.

Thanks to technological improvements, today we have photovoltaic systems or solar-electric modules that are so cost-effective that in many parts of the developed world they are being used as mainstream sources of electrical energy powering entire buildings and appliances from telephones to television sets. With further innovations, may be tomorrow's photovoltaics could make solar power emerge as a fundamental contributor to global energy production.

Solar energy is abundantly available; it is an inexhaustible, clean source of energy, does not generate any harmful greenhouse gases, and it is free! So wouldn't it be wonderful if the sun could become the world's main source of energy? Consider this. If photovoltaic systems were to be our main energy source, we would be able to create our own electricity, and we wouldn't have to be at the mercy of energy companies and their ever increasing prices of electricity. Photovoltaic solar panels fitted in homes and industrial facilities would also help combat climate change which is already a major concern.

Unfortunately, we don't yet have the technology to actually make renewables like solar power our dominant energy source. Currently, solar power plays an insignificant role as an energy source as compared to fossil fuels and nuclear power, with photovoltaics (PV) accounting for only a tiny fraction of the 4.8 TW total global power-generating capacity from all sources combined. But the upside to this scenario is that solar photovoltaics represent the fastest growing power-generation technology in the world today.

Solar Power in Europe and the world

As a Fellow of the Robert Bosch Stiftung, I had the opportunity to attend the Euro Science Open Forum

(ESOF) 2010 in Turin last year. One of the sessions focused on the use of photovoltaics across Europe, newer technologies being developed, the implications for society, and the ongoing endeavours of researchers for making solar energy a low-cost source of renewable energy. Dr. Heinz Ossenbrink from the European Commission – Joint Research Centre, Institute of Energy, and one of the eminent speakers, asserted that in much the same way as electronics have changed our life today, PV will change our energy system in the years ahead.

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Today, photovoltaics electricity is used in more than 100 countries. The maximum growth in the development of photovoltaics systems can be seen in European countries, with Germany and Italy leading the pack. Last year, the installed capacity of solar photovoltaics in the EU grew by an impressive 45%. Ossenbrink said the UK, which is a large consumer of electricity, is one of the European countries that needs to make greater efforts to increase PV electricity production. He also mentioned the ironic situation in Europe where some of the poorer countries like Portugal and Greece produce more PV electricity since they receive more sunlight, but the distribution of solar energy is greater in richer countries like Demark that receive comparatively very little sunlight.

Dr. Winfried Hoffmann, CTO, Applied Materials, Germany, and a solar industry veteran who also made a presentation at ESOF 2010, said, "PV can contribute to around 12% of power generation in Europe by 2020 if a paradigm shift towards electricity generation installations is achieved." Many other PV experts also think in a similar vein and assert that with proper government support and in an accelerated scenario, photovoltaics could meet around 4% of the world's electricity demand by 2020.

Europe currently accounts for 75% of the world's installed capacity in photovoltaic solar panels. Besides Europe, other countries achieving rapid growth in PV development are the US and Japan. China is the world's largest manufacturer of photovoltaic solar panels, though these are mainly for the export market. In contrast, the demand in the Chinese domestic market is still very poor. China is now focusing on developing its domestic solar market through strong government support for PV policies.

Of the approximately 1,46,753 Megawatts of electricity generated in India, 54% is coal-based, 25% from hydro, 8% from renewable sources and the balance is gas and nuclear-based. At present, PV systems make up just a miniscule part of India's installed power generation capacity, with the amount of solar energy produced comprising less than 1% of the total energy produced.

India - Potential

Actually, solar energy would be the perfect solution for power starved countries like India that are geographically located in the sunny regions of the world. Most parts of India have around 250-300 sunny days and we receive about 3000 hours of sunshine every year. Experts say that if even 10% of our deserts were covered with solar power plants, this would completely power the country's economy for years. According to Ernst & Young's recent renewable energy attractiveness index, India is among top 5 destinations worldwide for solar energy development.

Realizing the immense potential of PV solutions for transforming people's lives in India specially the over 450 million people who are deprived of access to grid electricity and have to use kerosene and other fuels for illuminating their homes, our Prime Minister launched the National Climate Change Action Plan in June 2008. The main goal of the plan is to increase the contribution of solar energy in the total energy mix of the country.

Though lagging behind other renewables now, in the long run, solar power is expected to outpace even wind, the premier renewable energy source in India at present. Another initiative by the Government of India is the launch of the Jawaharlal Nehru National Solar Mission which aims to build 20 gigawatts of solar capacity by 2020 reducing the country's reliance on coal and other fossil fuels that are mostly imported. This amount should provide enough power for 20 million homes in India. In order to encourage solar energy development, the Government is also providing various incentives and duty concessions for both manufacturers and users of solar products. Loans are made available through the IREDA at subsidized rates and income tax exemptions are provided for first 10 years of commissioning of project.

The PV Odyssey

The photovoltaic effect was first observed by the French physicist Alexandre-Edmond Becquerel in 1839 when he noted that certain materials produced

small amounts of electric current when exposed to light. Decades later, in 1905, Albert Einstein described the nature of light and the photoelectric effect on which photovoltaic technology is based, and later won a Nobel prize in physics for this work. In the 1960s, PV provided power aboard spacecraft. It was the energy crisis in the 1970s that led to PV technology being used as a source of power for non-space applications. For many years solar power was used mainly for thermal purposes as solar heaters for heating buildings and producing hot water. But with the development of PV technology, there was a huge expansion in the applications of solar energy. Today, most photovoltaic modules are used for grid connected power generation.

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Photovoltaic cells are made of semiconducting materials much like the ones used in computer chips. About 94 % of them have crystalline silicon as the primary material, a substance that is abundantly available, stable, and non-toxic. The ones with single-crystal or mono-crystal panels are cut from a single crystal of silicon, are completely rigid, and are more efficient than the other types, but are also more expensive. In contrast, polycrystal panels are less efficient, but are cheaper to make. They are made by cutting a slice from a block of silicon. Crystalline silicon cells have conversion efficiencies of around 15% or more.

Advances in PV Technology

"The house of the future will be solar-powered and self-sufficient!" This isn't wishful thinking, but a confident assertion made by Christophe Ménézo, coordinator of the "Solar Energy Team" at CETHIL, the reputed French thermal research laboratory. He says that solar energy will be "used in the future both to provide electricity, heating, and cooling (air conditioning) for housing, and to move towards energy self-sufficiency or even positive energy (producing energy in surplus of its own needs) for homes, apartment blocks, and offices, or even entire neighborhoods". Such contentions by scientists don't seem far fetched when we consider how the cost of conventionally generated energy is increasing each year, whereas that of PV has been declining progressively over the years due to technological advances and increases in manufacturing scale. In the 1980s, the average price of PV electricity was 95 U.S. cents per kilowatt-hour. Today the price has dropped to about 20 cents per kilowatt-hour. According to Hoffmann, with the emergence of even newer technologies, this could drop further to around 5 - 10 cents in the next 20 years.

Ossenbrink estimates that half of Europe will be enjoying grid parity by 2020. That is, more than 50% of the homes in Europe will find that electricity generated through solar photovoltaic modules is as cheap to produce as it is to buy electricity from the grid. In some places, such as parts of California and Southern Italy, grid parity is believed to be possible within a year or two. The US and Chinese governments are both taking steps in earnest to achieve price parity between solar electricity and fossil-based electricity.

The third speaker at the ESOF 2010 PV session Dr. Daniel Lincot from the CNRS Institute for Research and Development of Photovoltaic Energy (IRDEP), France, said the PV story has been characterized by a number of breakthroughs, but the crucial one that eventually brought about a dramatic breakthrough in cost was the emergence of the thin film solar cells.

For more than half a century, crystalline silicon dominated the photovoltaics industry. Even today, crystalline silicon cells make up 90% of the installation market. But these traditional cells are now being challenged by 'thin-film' solar cells that are micrometres or mere nanometres thick. Most of them are made from silicon in its amorphous form.

Since they use tiny amounts of silicon in a 'thin film' they are cheaper to make, but they are much less efficient than traditional crystalline silicon cells. In fact they are the least efficient type of photovoltaic solar panels and also the cheapest. In thin film solar cells, the thin layer of amorphous silicon is printed onto different surfaces such as glass, plastic or metal, making such panels very flexible. Basically, thin film photovoltaic technology involves a high-tech coating that transforms any surface that it covers into a solar-electric power source.

But since the last two years, thin film photovoltaics are also frequently made of materials other than silicon, such as cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS) which have a good market in the United States and Europe. Most thin-film photovoltaic systems have an efficiency rating closer to 10% as opposed to traditional silicon so-

lar modules that offer efficiency levels of around 15% to 17%. But experts are of the opinion that thin films could achieve higher efficiency than at present within the next three years.

Thin film technology has led to a growing global interest in Building-Integrated photovoltaics (BIPV). These are photovoltaic materials that are used to replace conventional building materials, thus actually becoming a fundamental part of the building.

For instance, CIGS technology has enabled the development of innovative, low cost solar shingles for roofs. The installation costs of such shingles are kept low because the conventional roofing shingles and the solar electricity generating ones are installed simultaneously by roofing contractors. In a BIPV system, photovoltaics modules can be integrated into different parts of a building such as the roof, skylights, walls, or facades. With BIPV being increasingly included in the construction of new buildings, many experts contend that this is the fastest growing segment of the photovoltaic industry today. Dow Chemicals has developed significant expertise in solar shingles based on the CIGS technology.

Besides CIGS and CdTe thin film photovoltaics, other potential alternatives to silicon are offered by nanostructured materials and photovoltaic polymers, but these are still at the basic research stage. Then there are the Grätzel cells that use dyes painted over the surface of nanometer-size particles of titanium dioxide which are then immersed in an electrolyte to produce electric current. However, this technology is still not feasible for commercial production. The last few years have also seen the emergence of third-generation thin-film photovoltaic devices in the marketplace, mainly in the organic photovoltaics (OPV) and the dye-sensitized cells (DSC) front. Both these low cost technologies have lower efficiencies as compared to conventional solar cells but they have the competitive advantage of substrate flexibility, and their ability to perform in conditions where the lighting is dim or variable. DSC is better suited to larger area BIPV applications while OPV can be used in lower power consumer applications.

Not as glamorous as photovoltaics, but still much more cost-effective, is the solar thermal power generation technology. Also known as Concentrating Solar Power systems, the technology uses concentrated solar radiation as a high temperature energy source to produce electricity using thermal route. This technology is appropriate for applications where direct solar radiation is high. India, located in the equatorial sun belt of the earth, receives abundant radiant energy from the sun. Hence, solar thermal power can play a significant role in meeting the country's energy requirements.

Challenges

Though the cost price per watt of photovoltaic electricity has dropped significantly in the last 25 years, it is still four times costlier than the 5 cents per kilowatt hour of electricity produced from coal. Also, PV may currently be the most environment-friendly renewable energy source of the future, but there are some environmental, safety, and health challenges involved in manufacturing, using and disposing of solar cells. For instance, Cadmium is very hazardous. Another matter that requires concerted efforts is achieving much higher solar cell efficiencies than the 15% or so at present, where less than one-sixth of the sunlight striking the cell actually produces electricity. Achieving grid parity as soon as possible is also of crucial importance for maintaining a strong and sustainable PV market.

Such challenges apart, it is a fact that solar energy technologies are indeed becoming cheaper. And as costs drop, there will surely be a huge shift towards the use of solar power in many countries like India which rely heavily on coal and foreign oil at present. Commenting on the strong growth in PV in 2010, Hoffmann reiterated that PV is a renewable energy system that will play a central role in meeting future energy demand and thus transform the world. No one can predict exactly how quickly solar energy will succeed in challenging the dominance of environmentally harmful fossil fuels, but there's no denying that PV technology is our best bet for shifting to a decarbonised energy supply.

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