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Solar energy—Photovoltaics

To follow up with my last column in the inaugural issue on solar energy, let's now circumscribe the subject to photovoltaics (PV). In using solar energy, PV is among the most viable and important technological pathways. Currently, PV is experiencing dynamic environments in both marketplace and technological development.

Market dynamic

Since the last writing, global events have evolved in a much divergent fashion, including an unprecedented, tumultuous financial debacle. To the momentum of photovoltaics, some events are viewed as upward lifting, and some are downward pressure. For example, EU countries' government incentives for solar energy, such as in Germany and Spain, have reached a plateau or subsided while the long-awaited solar energy tax incentives from the U.S. government were finally incorporated in the country's financial bailout program, extending them for a period of eight years. Meanwhile, oil prices plummeted below $70/barrel during the month of October. Psychologically, the reduced oil price may dampen enthusiasm about renewable energy. Yet in reality, oil contributes to U.S. electricity generation in a miniscule proportion and should not dictate PV solar energy development.

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It has long been a belief that the wide deployment of photovoltaics relies on the government's initiatives and financial incentives. Indeed, government plays a crucial role in the adoption and application of PV solar energy as an environment-friendly renewable energy source. Yet with or without the government's engagement, how fast and to what extent the PV can contribute to electricity generation in the U.S. and the world largely depends on two fronts: cost ($/W or $/Kwh) and technology.

Technology dynamic

In contrast to other technologies, photovoltaics shines on its intrinsic merit of direct conversion from light into electricity. Solar cells are essentially pn-junction diodes.

The conversion efficiency is built on the photon absorption efficiency, photon-to-electron conversion, the free path of electrons and electron mobility, which in turn are associated with the atom structure and defects of the semiconductor films. When the sunlight shines on the semiconductor solar panel, the light can be reflected, pass through or be absorbed. The absorbed sunlight (photons) by the solar panel is to be converted to electrons in the atom structure of the semiconductor of the solar cell material, resulting in electrical current in an electrical circuit. Since the solar energy spectrum covers a wide range of wavelengths from UV to infrared, low-energy photons will not be absorbed while high energy photons will contribute only a portion of their energy to the electrical current. Any parasitic effects will limit the efficiency of the cell.

Categorically, if we take the PV cell technology in three generations, they are thick film/ bulk polycrystalline silicon, thin film/amorphous silicon or other substrates and nano-based or organic cells. At the time of this writing, the thick film/bulk polycrystalline silicon, as the

first generation, occupies the majority of commercial application space, amounting to more than 85% of market. In thin film, there are a basket of technologies, involving various compound semiconductor materials, namely, CdTe, CuIndi-Se, as well as amorphous-Si, using CVD processes and other deposition techniques. Additionally, the crystalline silicon thin film on a metallic substrate is another technological approach in an effort to maximize the cell efficiency.

Thick film technology typically requires thick silicon wafer (250 μm - 120 μm) that makes up a significant material cost. However, when the silicon wafer is made too thin, problems during the subsequent screen-printing and firing process may occur. For thin film technology, there are also application concerns and technology challenges, such as photon absorption efficiency; In, Ga, Te supplies; Cd toxicity; sputtering quality; and thin film long-term reliability.

Currently, thick film technology can achieve 13-19% cell efficiency, and the typical thin film solar cell efficiency is around 6-9%. Shockley derived a theoretical efficiency limit of 32% under the assumptions of a single-junction semiconductor structure and a single electron-hole pair created for each absorbed photon. Technologies that can capture more sunlight per unit area, convert sunlight into more free electrons, avoid annihilation of electrons and holes in the structure, reduce efficiency-limiting defects in cell material, and utilize multi-junction cells are obvious tactics to achieve an increased efficiency.

Cost vs. grid parity

The cost as gauged by the power output by manufacturers in $/W or by energy use in the end market in $/kwh has been exceedingly higher than the conventional electric grid. This cost issue, including the upfront system installation expenses, has been the primary impediment to the adoption of photovoltaics for decades.

Going forward, as manufacturing capacity continues to increase and production techniques improve, the expanded scale and enhanced manufacturability will drive the cost down. Technologically, the global efforts to increase the cell efficiency are ever more rigorous and vigorous. The scale effect, coupled with the anticipated technological advancements, will move the solar-cell-generated electricity toward grid parity.

When the technology can offer the cost with grid parity or closer to that, photovoltaic solar energy will become an essential part of mainstream electricity in everyone's life.

The winning technology is the one that can deliver the desired economics. The world is longing for the winning technology and product leadership. In that, it is not an exaggeration to say that the product delivering grid-parity performance will sell by itself. The global race for an economically viable technology is on.

Dr. Jennie S. Hwang has been inducted to the WIT International Hall of Fame, elected to the National Academy of Engineering and named an R&D-Stars-to-Watch (Industry Week). Dr. Hwang has extensive experience in global market and international business in her executive capacities with corporate America and entrepreneurial businesses. She is a member of the U.S. Commerce Department's Export Council, and serves on the board of Fortune 500 NYSE companies and civic and university boards. Among others, she has served on National Research Council's "Globalization Committee" and " Forecasting Emerging, Disruptive Technologies Committee." Her education includes Ph.D., M.S., M.A. and B.S. degrees in engineering and sciences, respectively, and Harvard Business School Executive Program. An author of 300+ publications, she is also a worldwide speaker on trade, technology, business, education, and social issues. Tel: (216) 839-1000; E-mail: JennieHwang@aol.com. www.JennieHwang.com