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PROSPECTS OF SOLAR CELL TECHNOLOGY

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Introduction

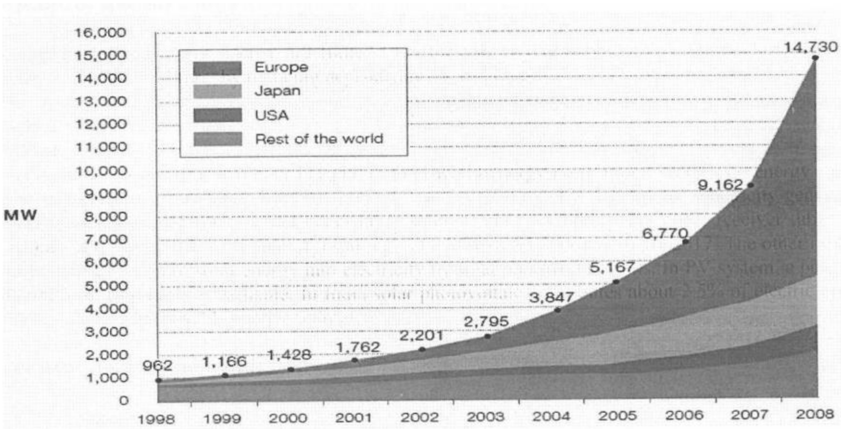
Energy is the key driving force of economic growth of any country. It is estimated that for a 5% rise in gross national product, a 7% rise in energy consumption is required.

Conventional sources of energy are finite. Thus the use of renewable energy sources would ensure energy security, in future, by reducing dependency on fossil fuels.

Solar Energy

Solar energy received in one hour is equal to total world energy used in one year. Solar energy can be used for generation of electricity in two ways. The first is through solar thermal electricity generation (STEG) using curved mirrors that concentrate sunlight onto a working fluid heat receiver tube. The national action plan has set a goal of installing 1000 MW of STEG capacity by 2017. The other method is direct conversion of solar energy into electricity by solar photovoltaic cells. In PV system, a potential for 20 MW/sq. km. is available. In India solar photovoltaic contributes about 2.5% of electric power generation from renewable energy sources.

Solar Cell Technology Growth



Solar Electric Energy demand has grown consistently by 20-25% per annum over the past 20 years. This has been against a backdrop of rapidly declining costs and prices.

This decline has been driven by a) increasing efficiency of solar cells b) manufacturing technology improvements, and c) economies of scale. In 2000, 1,428 Megawatts of PV were installed. This increased to 14730 Megawatts in 2008.

Rapid growth of on-grid sales in 2003 led them to be almost double those to off-grid customers, including industrial and habitation applications, mainly in developing countries. In both these off-grid markets, solar power is the 'fuel of choice', and is usually fully justified by its own economics.

The largest on-grid market by far to date has been Japan, where demand has been stimulated by large government funding programs. This is followed by Germany, where grid-connected applications are also stimulated by major market incentive programs.

Uses of Solar Energy

Anything that requires electricity could potentially be powered by solar energy. The main ways in which solar energy is used are as follows:

City Residential homes

Recent years have seen rapid growth in the number of installations of PV on to buildings that are connected to the electricity grid. This area of demand has been stimulated in part by government subsidy programmes and by green pricing policies of utilities or electricity service providers. The central driving force though comes from the desire of individuals or companies to obtain their electricity from a clean, non-polluting, renewable source for which they are prepared to pay a small premium.

Solar PV modules can be retrofitted on to a pitched roof above the existing roof-tiles, or the tiles replaced by specially designed PV roof-tiles or roof-tiling systems.

Industrial Applications

For many years, Solar Energy has been the power supply of choice for Industrial applications, where power is required at remote locations. This means in these applications that solar power is economic, without subsidy. Most systems in individual uses require a few kilowatts of power.

The examples are powering repeater stations for microwave, TV and radio, telemetry and radio telephones.

Solar energy is also frequently used on transportation signaling e.g. offshore navigation buoys, lighthouses, aircraft warning lights on pylons or structures, and increasingly in road traffic warning signals. Solar is used to power environmental and situation monitoring equipment and corrosion protection systems (based on impressing a current) for pipelines, well-heads, and bridges or other structures. Solar's great benefit here is that it is highly reliable and requires little maintenance so it's ideal in places that are hard to get to.

Water Pumping, lighting, heating in the Developing World

Apart from off-grid homes, other remote buildings such as schools, community halls, and clinics can all benefit from electrification with Solar Energy. This can power TV, video, telephony and a range of refrigeration equipment, which is available to meet World Health Organization standards for vaccine refrigeration, for instance.

To meet the largest power requirements in an off-grid location, the PV system is sometimes best configured with a small diesel generator. Solar energy can also power area lighting to enable more outdoor activities after dark or improve security, and to illuminate signs

Commercial buildings

On an office building, atria can be covered with glass/glass PV modules, which can be semi-transparent to provide shaded light. On a factory, large roof areas have been the best location for solar modules. If they are flat, then arrays can be mounted using techniques that do not breach the weatherproof roof membrane. Also, skylights can be covered partially with PV.

The vertical walls of office buildings provide several opportunities for PV incorporation. The first is as a "curtain wall system" that constitutes the weather barrier of the building. The second, as a "rain screen over cladding system" where there is an underlying weather barrier that provides the insulation and sealing of the building.

The third option is to create sunshades or balconies incorporating a PV System. Sunshades may have the PV System mounted externally to the building or have PV cells specially mounted between glass sheets comprising the window

Other Recreational Applications

Solar Power is frequently used in consumer product applications which require small amounts of energy (like calculators). Another frequent use is for Recreation Vehicles (RVs) and Boating to recharge the battery for recreational use activities

Solar Cell Technologies

Three key elements in a solar cell form the basis of their manufacturing technology. The first is the semiconductor, which absorbs light and converts it into electron-hole pairs. The second is the semiconductor junction, which separates the photo-generated carriers (electrons and holes), and the third is the contacts on the front and back of the cell that allow the current to flow to the external circuit. The two main categories of technology are defined by the choice of the semiconductor: either crystalline silicon in a wafer form or thin films of other materials.

Crystalline silicon solar cells

Historically, crystalline silicon (c-Si) has been used as the light-absorbing semiconductor in most solar cells, even though it is a relatively poor absorber of light and requires a considerable thickness (several hundred microns) of material. Nevertheless, it has proved convenient because it yields stable solar cells with good efficiencies (11-16%, half to two-thirds of the theoretical maximum) and uses process technology developed from the huge knowledge base of the microelectronics industry.

Two types of crystalline silicon are used in the industry. The first is monocrystalline, produced by slicing wafers (up to 150mm diameter and 350 microns thick) from a high-purity single crystal. The second is multicrystalline silicon, made by sawing a cast block of silicon first into bars and then wafers. The main trend in crystalline silicon cell manufacture is toward multicrystalline technology.

Each c-Si cell generates about 0.5V, so 36 cells are usually soldered together in series to produce a module with an output to charge a 12V battery. The cells are hermetically sealed under toughened, high transmission glass to produce highly reliable, weather resistant modules that may be warranted for up to 25 years.

Thin film solar cells

The high cost of crystalline silicon wafers (they make up 40-50% of the cost of a finished module) has led the industry to look at cheaper materials to make solar cells.

The selected materials are all strong light absorbers and only need to be about 1 micron thick, so materials costs are significantly reduced. The most common materials are amorphous silicon (a-Si, still silicon, but in a different form), or the poly crystalline materials: cadmium telluride (CdTe) and copper indium (gallium) diselenide (CIS or CIGS).

Thin film technologies are all complex. Thin film cells are laminated to produce a weather resistant and environmentally robust module. Although they are less efficient (production modules range from 5 to 8%), thin films are potentially cheaper than c-Si because of their lower materials costs and larger substrate size.

However, conventional c-Si manufacturing technology has continued its steady improvement year by year and its production costs are still falling too.

The emerging thin film technologies are starting to make significant in-roads in to grid connect markets, particularly in Germany, but crystalline technologies still dominate the market. Thin films have long held a niche position in low power (<50W) and consumer electronics applications, and may offer particular design options for building integrated applications.

Developing Technologies: Concentrators

Solar cells usually operate more efficiently under concentrated light. This has led to the development of a range of approaches using mirrors or lenses to focus light on to specially designed cells and use heat sinks, or active cooling of the cells, to dissipate the large amount of heat that is generated. Unlike conventional flat plate PV arrays, concentrator systems require direct sunlight (clear skies) and will not operate under cloudy conditions. They generally follow the sun's path through the sky during the day using single-axis tracking. To adjust to the sun's varying height in the sky through the seasons, two-axis tracking is sometimes used.

Concentrators have not yet achieved widespread application in photovoltaics, but solar concentration has been widely used in solar thermal electricity generation technology where the generated heat is used to power a turbine.

Developing Technologies: Electrochemical PV cells

Unlike the crystalline and thin film solar cells that have solid-state light absorbing layers, electrochemical solar cells have their active component in a liquid phase. They use a dye sensitizer to absorb the light and create electron-hole pairs in a nanocrystalline titanium dioxide semiconductor layer. This is sandwiched in between a tin oxide coated glass sheet (the front contact of the cell) and a rear carbon contact layer, with a glass or foil backing sheet.

These cells will offer lower manufacturing costs in the future because of their simplicity and use of cheap materials. The challenges of scaling up manufacturing and demonstrating reliable field operation of products lie ahead. However, prototypes of small devices powered by dye-sensitized nanocrystalline electrochemical PV cells are now appearing (120cm2 cells with an efficiency of 7%).

Developing Technologies: Multi-junction Devices

The breakthrough in the solar cell technology came with the invention of high efficiency multi-junction devices. The multi-junction devices are made by connecting several solar cells of different energy band gaps in series. Sunlight falls first on the material having the largest band gap. Photons not absorbed in the first cell are transmitted to the second cell, which then absorbs the higher-energy portion of the remaining solar radiation while remaining transparent to the lower-energy photons. These selective absorption processes continue through to the final cell, which has the smallest band gap.

Absorption of light with multi-layer cells increases the efficiency of solar cell many folds. Efficiency up to 41.6% has been recorded by efficient concentrator triple junction solar cells.

Conclusion

Solar Energy is already the "energy source of choice" in many circumstances where power is required, but the user does not have the option of connecting to a local electricity grid. This market segment is providing the economic platform from which a self-sustaining, commercially driven, high technology industry is emerging.

Over the last two decades, the trend of solar energy prices has been consistently downwards, driven by continuous advances in PV technology and manufacturing economies of scale. Investment in solar energy today is set against an economic backdrop of an industry that will approach break-even costs with other grid connected energy sources at the end of this decade.

With 5568 Megawatts of global incremental solar capacity installed capacity last year, solar energy is still a tiny fraction of the world primary energy market. However, its reduction in unit costs has yielded growth rates and market share gains that suggest solar energy has the potential to become a mainstream energy source in the foreseeable future, as part of a growing Renewable Energy sector.