Pressure Sensitive Tape Materials and Technologies Utilized by the Thin-Film, Crystalline Silicon, and Roll-to-Roll (R2R) Photovoltaic (PV) Solar Module Manufacturers (Presently and in the Future)

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Photovoltaic's (PV) are simply semi-conductor type devices that produce electricity when exposed to light. In fact, the word "photovoltaic" means "electricity from light". Sunlight knocks out electrons from a photovoltaic material, and subsequently flows out of the device as current. Since PV Modules generate DC current, the current must be fed into an inverter to generate AC current which can then be utilized by the appliances within a residential home. Renewable energies such as Photovoltaic's (PV) do not produce hazardous green house gases, specifically carbon dioxide, and thus have a positive influence on the climatic balance within the atmosphere. There are clear advantages for the use of solar energy when compared to coal and nuclear.

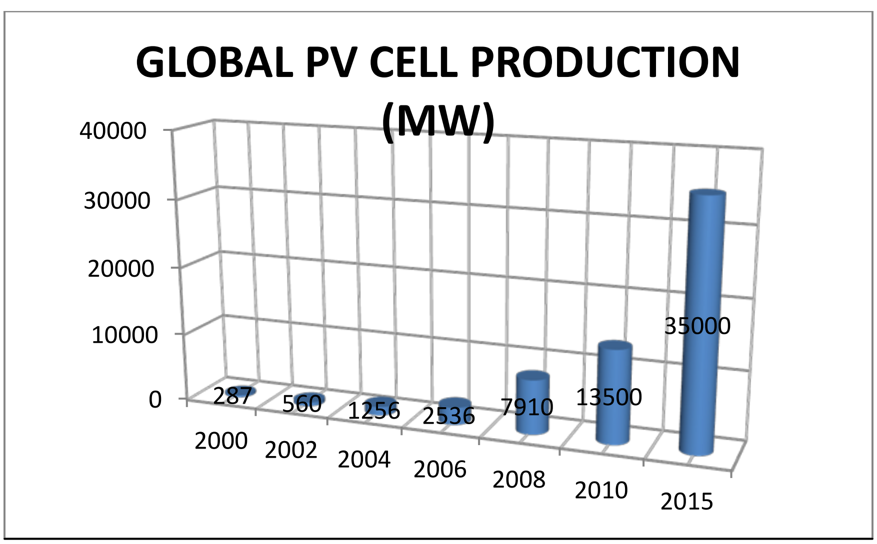
Photovoltaic modules utilize sunlight directly. The primary absorber utilized in 82% of the modules remains crystalline silicon. By 2012E, there will be approximately 25% of the modules manufactured using TFPV technology. This direct process is different than indirect as is the case with concentrating solar power (CSP). This process involves the use of lenses or mirrors to concentrate a large area of sunlight into a small beam. This can be utilized to heat liquid or superheat water, producing steam and converting to mechanical energy, and ultimately electricity. The ability to store this heat, for later use, allows this to be an ideal energy process for power plants. Several types of CSP plants exist, the most common including Parabolic Trough, Fresnel Reflector, Stirling Dish and Solar Power Tower. The largest solar power plants (354 MW SEGS) are CSP. But multi-megawatt PV plants have also been built.

Parabolic Trough Power Plant

Roof Mounted & Ground Tracking Solar Panels

The manufacture of solar cells and photovoltaic grids has expanded dramatically in recent years due to the growing need for solar energy. *Demand* estimates from 2000 to 2010 have been reported as high as 51% (average annual rate), driven by government programs such as feed-in-tariffs, power purchase agreements, government rebates, tax credits, government guarantees, and other supported programs. Photovoltaic *production* has been nearly doubling every two years – increasing by an average of 30-45 percent each year since 2002 – making it the world's fastest-growing energy technology. Even though there is a range of production MW being communicated by the news sources; i.e., for the actual volume of solar panels manufactured, there is an agreement as to the growth being excellent and averaging well over 30%; i.e., 30-45% respectively.

Even if one utilizes the minimum reported values to date (*Photon International*), one can see very quickly that the predicted slope for global solar cell production will be excellent through 2015 (*note*: *estimate for 2015-Nanomarkets*).



Other forecasts by organizations such as: GTM Research depicts similar growth levels; however, also show outstanding regional growth in North America as well as the Asian segments of Taiwan and China.

Very impressive growth rates have been experienced in the past decade, not to mention the previous two to three years respectively. PV *demand* has been growing at over 45-50%, driven by several factors, not the least of which have been European feed-in-tariffs. This has allowed global demand to exceed the available supply chain. Driven by federal subsidies in Germany, Spain, Japan, and Italy the demand has allowed for new module entrants into this space. Estimated in 2010 having 16.1 GW of capacity, the market does not seem to be constrained by limitations in supply.

This backing off in the gold rush is seeing a few alternative drivers and customers arise into this critical space:

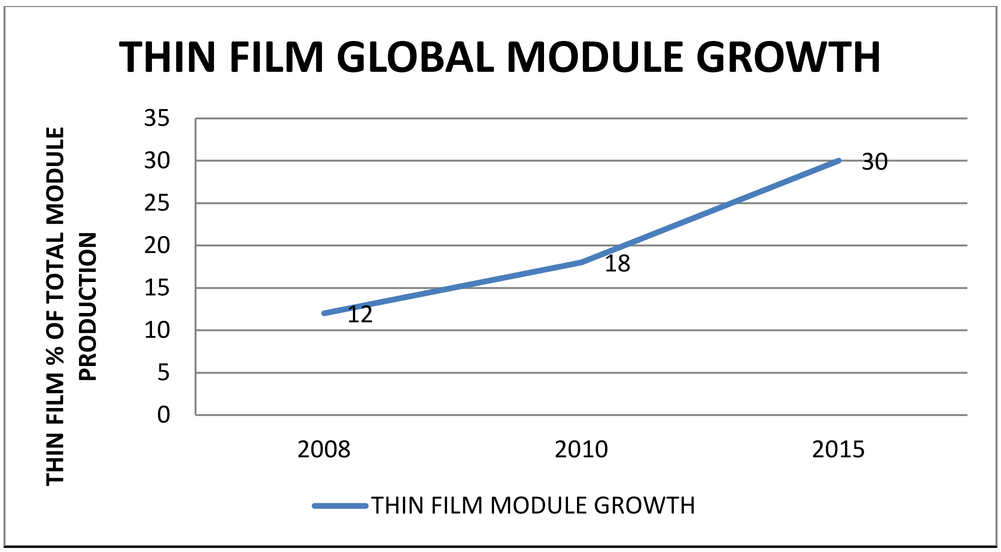
- Previously the "Gold Rush" was driven by feeding into a single uncapped feed-in-tariff market. Spain was an example for 2008 and Germany for several years including 2009 and the first half of 2010. This process usually follows governments reducing and capping subsidies, and the supply chain looking for the next focused market to provide their wares.
- The next platform (much better in long term opportunity) is to focus on controlled growth in a larger number of markets providing a platform to remove risk and provide a steady flow (predictable flow), to the marketplace.
- With a reduction of government subsidies, the combination of remaining and new subsidies, along with reduced cost per watt of the modules and increased value proposition of the solar investment (driven by the project developers and financiers), collectively represent the drivers; i.e., versus the previous sole focus on feed-in-tariffs of an individual country.
- One needs to now look at more than policy for an individual F-I-T (Feed-in-Tariff) country, but also technology and financing opportunities and availabilities. Everyone recalls the difficulty in securing financing in 2008 and early 2009, as the latter becomes more attainable and flexible, as well as the cost per watt driving to parity, the index of importance becomes more normalized between these three entities. In fact, the ability of the technologies to be stand alone, to fossil fuel and nuclear, allow for a much larger driver into the growth model for PV and Solar Thermal technologies.

One can review several estimates of module and cell production showing a much higher production level for c-Si over the up and coming Thin Film technologies such as CdTe, a-Si, and CIGS. The benefit for the consumer is rising at a very fast rate; i.e., in the c-Si area $/kg has been reduced from $450/kg for silicon to $40-$80/kg respectively. The initial lack of availability has now turned into an adequate supply base. This along with lower cost processes and increased capacity of the Thin Film technology (some CIGS reaching close to 20%), has resulted in a reduction in module costs. This is allowing for PV to drive toward grid parity.

As discussed earlier; policy, technology and financing all contribute to the demand. When government policies are more moderate in nature, pricing (technology & finance) becomes the driver for the demand curves. Global PV demand has been estimated by some to go from approximately 6 GW at $3.00/watt to an outstanding 16 GW at $1.00/watt. This was all calculated for the year 2010 and assumed a model of very limited government subsidy. This of course was not the case, but provides an example of how the price drives demand and what can be expected when the technology helps to lower the $/watt even without governmental support.

With the average selling price per watt being lower for thin film technology, and over 60% of the manufacturers in the USA representing this area of PV semiconductor, North America is in excellent shape for increasing share of the PV supply base for the upcoming years. Add to this, that CIGS and CPV (Concentrated Photovoltaic's) manufacturing is largest within the state of California, the drivers are once again positioning NA as a potential major supply base for the PV industry. Of course, it also doesn't hurt that the number one world-wide module manufacturer, First Solar in Perrysburg, Ohio, is a part of the NA.

Even though thin film will be representing the majority of modules being manufactured in the USA, the rest of the globe will continue to be represented by a majority of c-Si. The trend; however, will continue to be the growth of TFPV at the expense of c-Si.



Demand in the USA is rapidly expanding due to falling system prices, stimulus funding and new regulatory incentives. USA is poised to become one of the largest global demand centers for PV. The USA will experience one of the most dramatic growth trends of any PV market. When reviewing the USA, one has to see this market as an amalgam of 50 states. Each having their unique incentives, electricity pricing, regulations and political process. Approximately, 16 states presently represent 97% of the market.

A number of factors influence where the manufacturing facilities are located: state incentives, power prices, cost & availability of skilled labor, tax burdens, and proximity to the ends demand. Grants, tax credits, exemptions, loans, loan guarantees all play an important role in defining the locations. The primary type of funding opportunities includes:

- Federal Cap and Trade (Incentives for emission reduction of pollutants)
    - Companies which pollute more than the cap must buy credits from those who pollute less. Transfer of the allowances is defined as trade.
- Uncapped Residential Investment Tax Credit
    - Eight years; i.e., through 2016
    - Remove $2000 max on expenditures
    - For properties installed after 12/31/08
    - Allows to offset annual tax liability

- PPA (Power Purchase Agreement)
    - Usually an independent power producer has a 5-25 year contract with the power purchaser…this allows one to raise financing for a known revenue stream.
- FIT (Feed-in-Tariffs)
    - Obligation for the utilities to purchase utility (electricity) from all eligible participants. This provides (1). Guaranteed grid access, (2). Long term contracts for electricity and (3). Pre-defined methodically calculated price for electricity.

Even though 28% of the USA production is represented by California, other locations will be growing in percentage of the overall USA manufacturing market. By 2012, the USA is expected to consume over 40 million sq meters of glass and encapsulants.

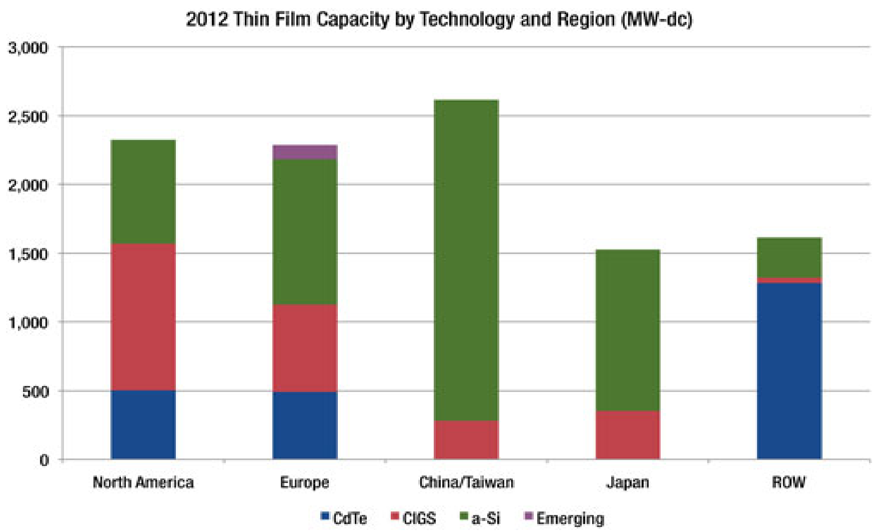
The ability to deposit thin film at levels up to 100 times thinner than the crystalline counterpart provides for significant advantage and benefits. It maximizes the surface area of the TFPV and allows it to be integrated easily with flexible PV building materials which are typically easily adhered to. One could also incorporate this technology into glass which would allow it to be utilized in architectural and window applications.

Thin film PV technology can also be produced by roll-to-roll versus batch processes needed for the cutting of the ingot for the crystalline silicon counterpart. This certainly allows one to generate a lower cost per watt, as well as countering the issue of future availability of crystalline silicon. As an example, amorphous silicon is approximately 3 microns versus crystalline silicon being 300 microns in thickness.

This very thin technology is produced by depositing an active PV layer on a suitable plate or sheet such as glass, plastic or metal. The PV active material is in the form of a thin film. Two of the most common elements in thin film are Cadmium Sulfide/Cadmium Telluride (CdS/CdTe) films or amorphous silicon films.

Other types of thin film PV elements are the copper indium disulphide (CIS), copper indium gallium diselenide (CIGS), copper indium sulfur diselenide (CISS) and gallium arsenide photovoltaic elements. Application methods vary but sputtering has been one of the most common application methods for companies such as First Solar, Xunlight, Sencera, Unisolar W&K, and others; i.e., PECVD (Plasma Enhanced Chemical Vapor Deposition).

Shown below are the TFPV technologies per region and the confirmation that the higher efficiency, lower cost technologies are represented well within North America. Amorphous silicon is expected to represent lower percentages, of the total, as CIGS and CdTe (higher efficiency modules) increase their penetration within the market space. In addition, as CIGS manufacturing volume increases, margins are also expected to follow suit.



Additional technologies are making in-roads, such as third generation technology (OPV and dye-sensitized). Predominantly where low cost, flexibility, and 3-5 year durability are required, these technologies are starting to play a more favorable role. Another growth technology has long term durability (20-25 years), and has made significant strides due to a more competitive position; i.e., CPV. Solar tracking, high efficiency cells and improved optics have allowed upwards of 40% efficiencies to be generated with Concentrator Photovoltaic's (CPV). In addition, approximately 50% of the CPV companies are in the USA, with the majority springing up since 2005.

Since one hour of solar energy hitting the earth is capable of meeting the world's demand for one full year, it is not surprising that harvesting this free energy source is such an exciting and challenging area of interest for so many organizations around the world. With many of the ultimate customers being concerned about the appearance and aesthetics of highly visible collectors on roofs, as well as ground level grid systems, there has been a massive level of interest and effort along the direction of BIPV systems. Indeed, photovoltaic systems integrated into the rooftops allow for a more aesthetically pleasing, yet very efficient and effective, electrical source. Once installed, BIPV systems are less noticeable but produce free electrical energy for a home or business. BIPV systems are not only applied into roofs but also into glass, walls, awnings, walkways, and façade materials.

BIPV is used significantly in Europe, but just starting to come to existence in the U.S., with companies such as United Solar Ovonics and Xunlight providing the flexible TFPV roll-to-roll products to fabricators, architects, distributors, and installers.

Traditional means of capturing solar energy on buildings involved the addition of solar panels on the rooftops using a fixed frame network. This results in an add-on condition and is more costly than the BIPV approach. When one integrates the solar panel into the building envelope, money is being saved due to it being a part of the structural network, which thereby reduces the building costs.

Photovoltaic Technologies

Thin Film Technology

Several examples exist for the amorphous silicon technology. The most prominent in the U.S. is United Solar Ovonic, LLC. The amorphous technology is typically less efficient than the crystalline counterpart. United Solar has overcome this by what they call their triple junction technology. This involves three stacked semiconductor junctions, each absorbing a different wavelength of light.

Alternatives to the typical amorphous silicon thin film and crystalline systems have also surfaced. The most prominent of these include: copper indium disulphide (CIS), copper indium gallium diselenide (CIGS), and cadmium telluride (CdTe).

Probably the most prominent is First Solar CdTe technology using a sputtering process and producing the modules in a batch process. Quoting that they are less than $0.83/watt (manufacturing cost) this technology is clearly very competitive in nature. Toxicity of the cadmium and the future direction and acceptability is the large question. For now they are growing at an accelerated rate reaching $2 Billion in revenues in 2009 and approaching $3 Billion in 2010.

Crystalline Silicon Technology

Several types of silicon technologies exist. Single-crystal-monocrystalline, multicrystalline, and amorphous silicon represent the three primary technologies. The first two types are generally utilized with the 82% of manufacturing technology we refer to as crystalline silicon, while the 18% of thin film technology; i.e., the portion of which silicon is utilized, is referred to as amorphous silicon.

Organic Movement of PV Materials

Thin film organic PV materials have the promise of low cost, flexibility and roll-to-roll manufacturing. Governments such as Germany, along with companies such as BASF, Merck and Scott have significant investment with this type of TFPV technology. Printing of this type of system shows great promise; however, stability, longevity, and encapsulation improvements require additional advances.

Another technology is the dye sensitized technology. Companies like Dyesol utilize nanotechnology and show 8% efficiencies. G24i is another company utilizing this type of science. These types of chemistries, if successful, clearly will be instrumental for providing cost-effective BIPV candidates.

Commercial OPV will be challenging. Organic materials have poorer conversion levels then their inorganic counterparts, as well as being very susceptible to water vapor and oxygen. Konarka is the predominant player in this arena. To date, their technology is utilized in small niche segments such as: folding packs for recharging of phones and laptops, solar purses and backpacks, and additional unique items. Their technology and product line is touted as a 3-5 year durable product without much chance of achieving 20 year durability; i.e., until the substrates and packaging are modified. The potential is huge within the roofing industry; however, time will tell if these dye/organic technologies will be commercially viable on a mass production scale.

Generic Module Constructions

Several module constructions and material sciences are utilized by the OEM. This is very specific to the type of technology and process being utilized. A few of the constructions are noted below:

Technology Layers for Rigid Glass/Backfilm Crystalline Silicon Laminates

- Transparent Glass
- Encapsulating Film
- Silicon Cells
- Encapsulating Film
- Backfilm Laminate – TPE/Triplex PET/Powershield®/Others.
- Curing Process

Technology Layers for Film/Backfilm Thin Film Laminates

- ETFE/FEP
- Encapsulating Film
- Non-Woven
- Encapsulating Film
- PECVD (a-Si Typically)
- Back-Structure – Polyimide/Stainless Steel
- Curing Process

Technology Layers for Glass/Glass Thin Film Laminates

- Transparent Glass with TCO Layer
- Sputtering of Thin Film Technology
- Edgeseals/Charge Collectors
- Encapsulant
- Second Later of Glass
- Curing Process

Specifications & Performance Requirements

I.E.C. Specifications

The International Electrotechnical Commission has successfully developed standards for crystalline silicon modules (I.E.C 61215) and thin film modules (I.E.C. 61646). Both examine all of the conditions and parameters for open-air exposure; however, the TFPV materials are also subjected to additional testing which will take into consideration all of the degradation performance expected with amorphous silicon and other TFPV technologies; i.e., when subjected to temperature, moisture, and irradiation.

The specific standards and tests certify the passing of only the specific module type which has been evaluated. It cannot be grandfathered or transferred to an extension product type. The module design is said to meet the I.E.C. certification when it meets the following criteria:

- The degradation of the maximum power output, at standard test conditions (STC), does not exceed 5% following each test or 8% following each test sequence;
- The Insulation Testing Requirements are met;
- There are no signs of visible damage;
- No sample has shown a ground fault or open circuit; and
- For TFPV only: final light soaking output power cannot be less than 90% of manufacturer specified minimum value.

U.L. Specifications (UL 1703)

This Underwriters Laboratories (U.L.1703) standard is for *Flat Plate Photovoltaic Modules and Panels.* This specification covers modules which are installed on or a part of a building, in addition to being freestanding usually adjacent to the building. The maximum system voltage is 1000V and not intended for higher voltage levels. Components which provide an electrical connection or some type of mounting are also included within the body of this specification.

Products sold into the US market are required to have the UL 1703 approval.

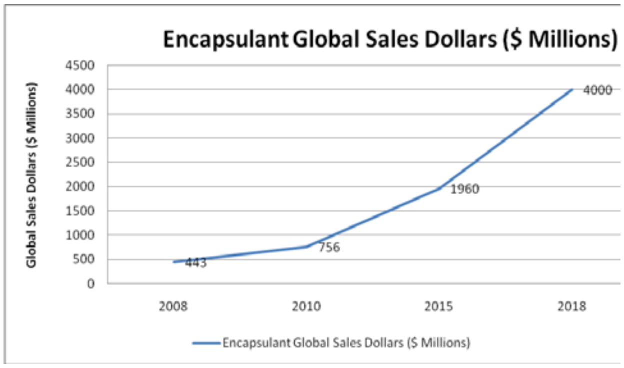
U.L. 510 Specification

This specification is for Polyvinyl Chloride, Polyethylene, and Rubber insulating tapes which are utilized for electrical insulation at not more than 600V and 80C. They are typically utilized on joints and splices in the wire & cable market in accordance with the National Electrical Code ANSI and NFPA 70. They have been adapted by the Solar Industry for BusBar and BusBar connectors, as well as many of the other pressure sensitive tape products.

Materials Utilized within Modules

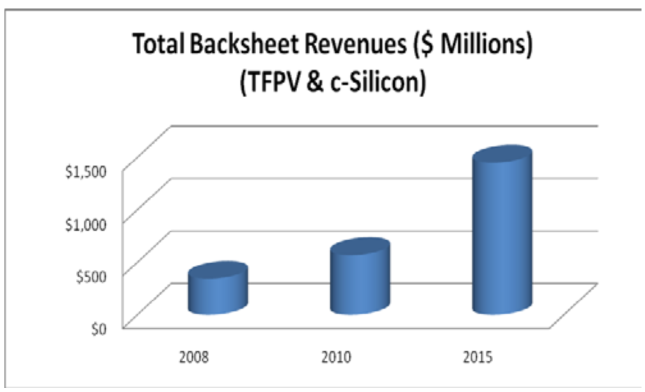
Encapsulating Systems & Backsheets

Encapsulant revenue growth projected through 2017-2018 is truly outstanding. More than doubling between 2010 and 2015, and then again by 2017-2018. During the latter period, it is anticipated that the total revenue for encapsulants could reach approximately $4B.



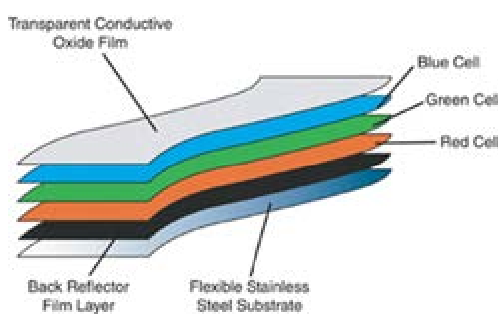
Backfilm Laminates

The growth of global backfilm laminates is anticipated to be following the identical trend as encapsulants. Growing from $344M in 2008 to $1,450M in 2015.



Frontfilms

Frontfilm (presently mostly Tefzel®) is expected to be in the $300-$500 million dollar sales level prior to 2015. Much of this will be in markets such as: Metal Building, Military, Architectural, Commercial and Specialty. They will be defined by terms such as BIPV (Building Integrated Photovoltaic's) and R2R (Roll-to-Roll). The technology which will be utilized will be focused on flex based CIGS and a-Si, with the former becoming a larger part of the market share.

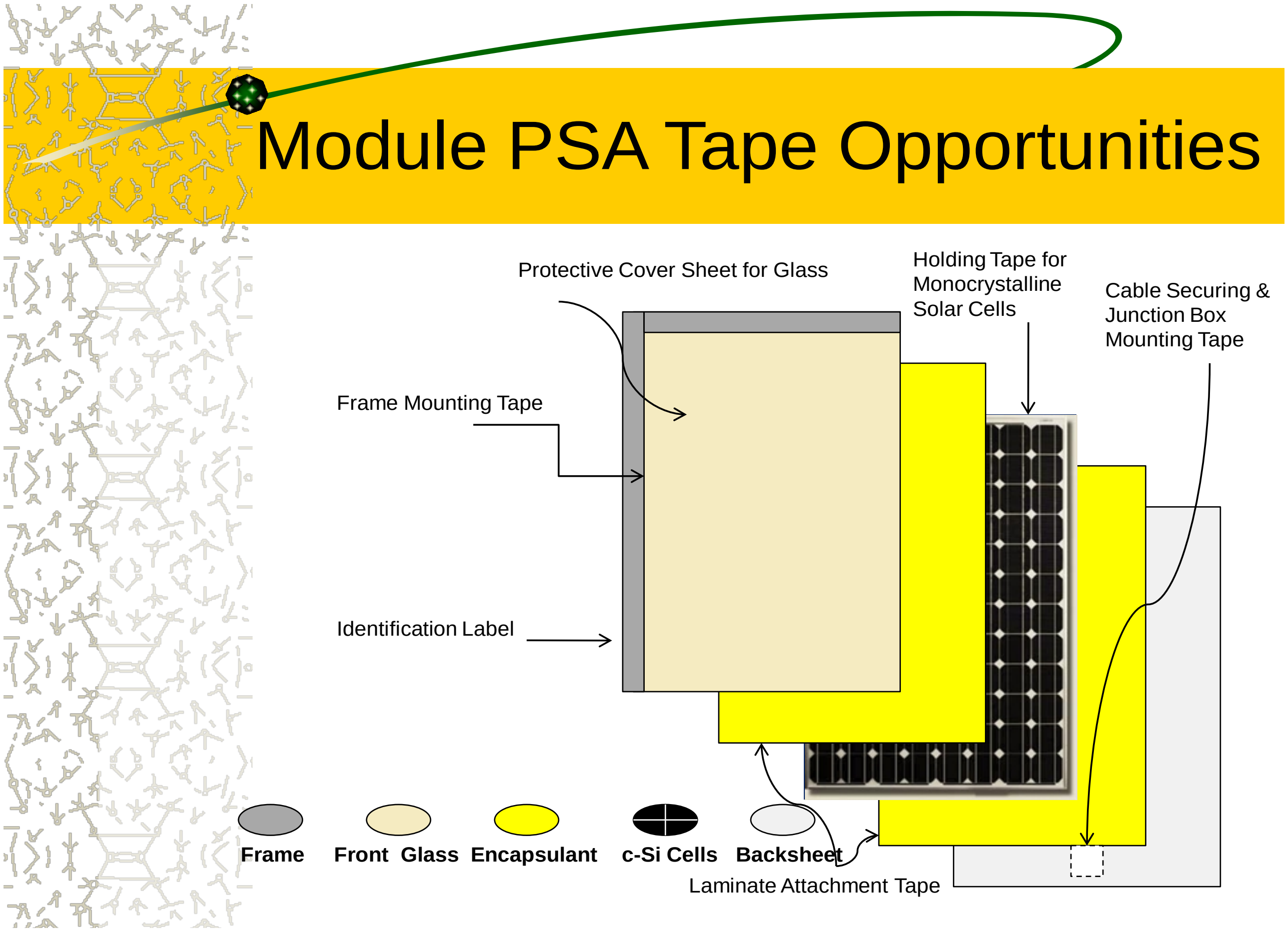


PSA Tapes & Materials (C-Si)

Tape and adhesive opportunities are plentiful for the solar module market segment. Some of the applications being utilized include:

- Frame Mounting Tape
- Identification Labels
- Protective Cover Sheet
- Cell holding Tapes
- Cable Securing and Junction Mounting Tapes
- Laminate Attachment Tapes
- Current Collection Tapes
- Miscellaneous Others

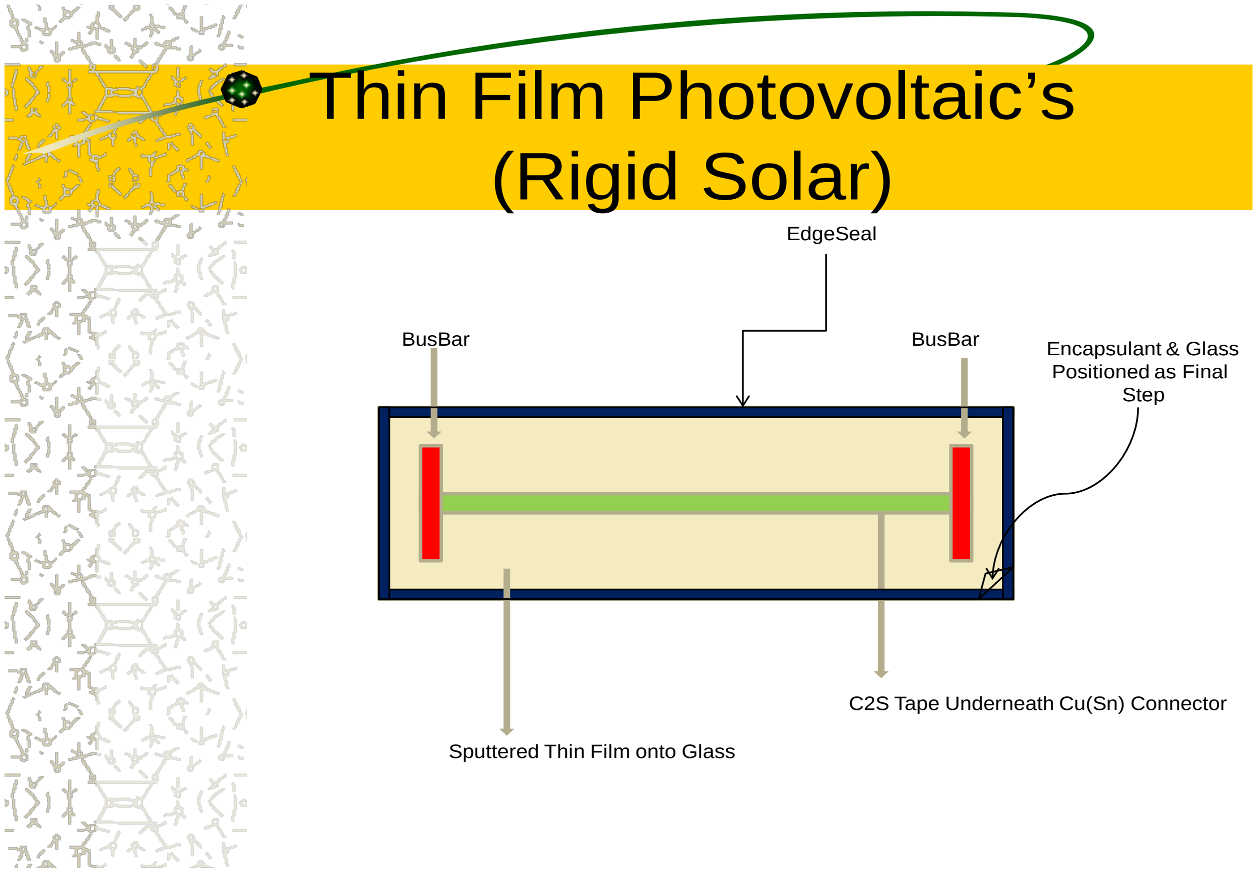
With total solar material sales reaching almost $9B in 2010 for C-Si, as well as projected to increase over 50% by 2015, the opportunities for the adhesive and tape manufacturer are outstanding.



PSA Tapes & Materials (TFPV)

With total material sales being shy of $2B for the TFPV market, this segment also lends itself with excellent opportunities for the raw material suppliers. Some of the materials being utilized include:

- Edgeseal
- Charge Collector Tapes
- Encapsulant
- Glass
- Conductive Technology
- Junction Box & Mounting Tape
- Miscellaneous

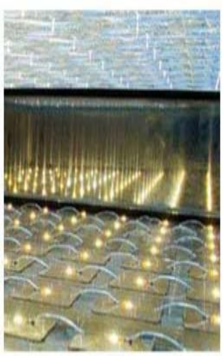


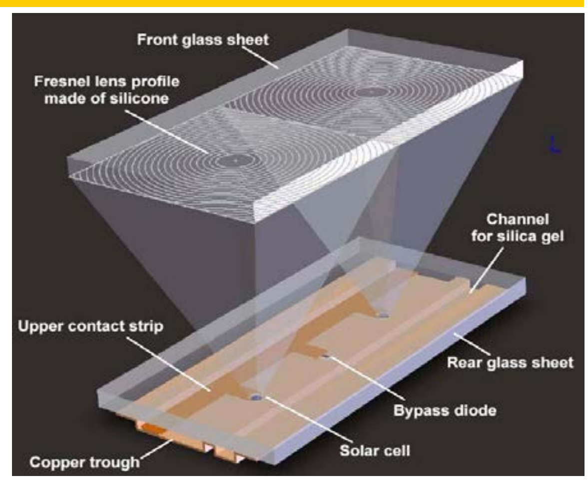
Concentrated Photovoltaic (CPV)

Concentrated Photovoltaics (CPV) have reached levels of efficiencies exceeding 41% respectively. Utilizing triple junction technologies such as: GaInP/GaAs/Ge. This along with the utilization of concentrating lens technology, composed of either silicone or acrylic, has allowed for this excellent level of efficiency at 500-1000 Suns.

Several different types of CPV designs exist, some with copper troughs and secondary lens systems, and some without. Typically, this type of design is utilized in areas: with excellent primary radiation (non-diffuse source), and greater then 1MW of requirement. Once again, California leads the way with over 50% of the manufacturers located in the west coast region of the USA.

Concentrated Photovoltaic's (Concentrator Sub-Modules w/ &w/o a Trough Design)





Concentrix Solar

Module Production

The global installations for the solar market grew over 100% to approximately 17 GW. The US is about 5-6% of the market, demonstrating the outstanding growth levels below:

- 3.9 MW in 2000
- 435 MW in 2009
- 878 MW in 2010

This is making the US one of the most valuable PV growth markets in the world. The module and critical production information forecasted for 2015 includes:

- $40.8 billion in 2015 forecasted
- 3.5 billion sq ft in 2015 forecasted
- 82/18% c-Si/TFPV to 70/30 in 2015
- Cell production 35 GW in 2015 forecasted

Summary

Growth of Solar Modules is forecasted to increase dramatically for at least the next decade. This provides outstanding opportunities for the downstream segments and participants, as well as the material suppliers. For manufacturers of: adhesive & sealants, films & sheets, laminates and tape suppliers this market segment represents one of the very few, with dramatic growth opportunities. The solar space looks to be an outstanding area of growth, for organizations which can provide improved efficiencies and performance, at competitive pricing.

With the availability of financing, controlled growth subsidies by government, and pricing levels driving toward grid parity, solar technology will become of the most important energy sectors for the future.

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