Forum for Global Knowledge

Emerging Technologies and Development

IIT Bombay, October 25 – 27, 2013

# Components for photovoltaic panels, a case study

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**Keywords**
Photovoltaic panels, PV modules, solar energy industry, films for encapsulants, Ethylene Vinyl Acetate EVA, China PV indsutry

## Abstract

**This is an example of a study recently made by Pardos Marketing**

A study has been made in 2011, to better understand the EVA film encapsulants for the protection of photovoltaic cells in solar panel modules.

The key objective of the study was to find the precise structure of the EVA film, and processing costs.

One very interesting aspect of this study, for an industry that really started in 2007, was the very fast shift from Europe to China, the extremely fast changes in the industry geography, the play of free market and government subsidies, the very rapid growth. All these aspects are still boiling up in the solar industry. The photovoltaic industry is still in its infancy.

EVA encapsulation films are formulated with light UV stabilizers, antioxidants, adhesive promoters (silanes), cross linking agents (peroxides). The extruders of these films, the raw EVA resin suppliers, the compounders, the extrusion machine manufacturers, the module manufacturers who use the films, are all amazingly discrete about the composition, the particular “recipes” of which the EVA encapsulants are made.

The EVA encapsulant films are in developed countries, Europe, US and Japan, so far, and the modules are in Asia, mainly China. In this very volatile situation and outlook, the optimism about the PV industry development remains strong, in spite of a slowdown in 2010-2011, now overcome.

The study methods were extensive desk research and over 300 contacts, of which 100 fruitful interviews.

**Outline** **Pages**



# Presentation of Pardos Marketing

Pardos Marketing is a consultant specialized in industrial market studies, focused on plastics and applications worldwide, active for the last thirty years.

Full details on Pardos Marketing, presentation, history, many study themes over the last 30 years, papers, can be found on the website of Pardos Marketing, www.pardos-marketing.com. However, the website needs updating, as the last updating was 18 months ago.

Many of the themes of former and recent studies are listed in the website, under the part Studies.

Studies range from mostly commodity plastics in earlier days, to increasingly specific and more specialty plastics and applications in recent years. Emphasis is on perspectives of the plastics markets, new products and trends, to provide recommendations for the best strategy and development of the client companies.

Pardos Marketing clients include many large international petrochemical and plastics producers worldwide, in Europe, USA, and Japan.

Over the years, many studies have been completed, in all industrial applications where plastics are present, which means almost all industries, including, in decreasing order of the relative importance of plastics, packaging, building construction, electricity and electronics, agriculture, automotive and all vehicles, industrial applications, medical products, and innumerable consumer goods.

To summarize all this experience Françoise Pardos is now completing a multiclient study entitled Plastics and applications in the world and trends to 2030.

As an example, and to show how single client studies are made, a study was completed a few months ago on EVA film for encapsulants in photovoltaic, PV, panels, worldwide.

# Single client study on EVA film as photovoltaic cell encapsulants

## Study methods

The study was done with two approaches:

**Desk research**, drawing from Pardos Marketing knowledge and experience and access to a number of data banks, plus general literature search.

**Interview program**

Over 300 contacts have been made worldwide. There were about 100 fruitful interviews with manufacturers of photovoltaic modules, EVA sheet and competing materials suppliers, machine manufacturers, and other sources of contributive interest.

Most interviews, over 300, have been made by telephone, after the well-proven technique of prepared telephone interviews. Once the respondent has been identified, an e-mail is sent, outlining the contents and topic of the questions to be discussed. A telephone appointment is then made, so that the interview is as close as possible as to what a face-to-face interview would be. In principle, and as past experience shows, prepared telephone interviews are very well accepted by respondents, quite fruitful, and appreciated by all for saving time.

## Description of photovoltaic solar panels, or modules

Photovoltaic panels are complex structures, solar cells sandwiched into glass and metal frames.

**There are two types of commercial solar cells**.

**Crystalline silicon (c-Si),** produced for more than three decades, is about 90% of the market.
**Thin-film**, introduced 12 years ago, makes up the remaining 10%.

Older-style c-Si solar cells all share similar construction, with slight variations. They use silicon wafers sawed from rods of pure silicon to convert light waves into electricity. Silicon is expensive, and the wafers are fragile, so modules require special handling throughout production.

**Crystalline silicon modules** consist typically of a glass top sheet, followed by EVA encapsulation film, silicon-wafer solar cells, another EVA film, and finally a back sheet of laminated fluoropolymer and other films. All these components make c-Si modules expensive, but they have an operating life of 20 to 25 years and electrical efficiency of 14% to 23%.

**Thin-film solar cells** are the second generation, holding the promise of lower cost. Many are made by continuous roll-to-roll production, whereas crystalline silicon is a batch process. “Thin-film” refers to the light-absorbing semiconductor layer, which is indeed a thin film of conductive metal, vapor-deposited in a vacuum on a thin substrate like glass, aluminum, stainless steel, or polyimide.

Thin-film modules are much thinner, less expensive, and less fragile than crystalline silicon, but they have a shorter track record since most are recently developed. Their electrical efficiency ranges widely from 6% to 20%, depending on the semiconductor. Thin-film cells use one of three major semiconductor materials: a-Si (amorphous silicon), CdTe (cadmium telluride), or CIGS (copper-indium-gallium selenide). They also have one or two protective encapsulation layers of plastic films, a front sheet of glass, and sometimes a back sheet of glass or plastic.

Encapsulant films are used both for crystalline and for thin film, to protect the delicate semiconductor active solar material in photovoltaic solar devices. The encapsulant makes up 3-10% of the total cost of the solar module but it is considered a very important and sensitive component.

The most widely used encapsulant to protect the PV cells is EVA film. Alternative thermoplastic encapsulant films have been introduced to reduce lamination time. Thin-film a-Si modules are sometimes sandwiched between glass front and back sheets using PVB, polyvinyl butyral encapsulation films, because of PVB long use in automotive safety glass.

Several companies have introduced thermoplastic polyurethane TPU encapsulation films, ionomer films, polyvinyl fluoride PVF.

## Study topic and scope

The study topic was to provide a detailed cost analysis of EVA (ethylene-vinyl acetate) film/sheet material used in producing photovoltaic (PV) modules. The EVA film/sheet is used to encapsulate the active silicon solar cells.

The PV industry, as well as demand for EVA sheets, started growing very rapidly due in large part to government subsidies around the world. The economics of the PV modules require a cost reduction roadmap to enable the industry to be cost competitive without the government subsidies that are now disappearing.

With this study the client wanted to have a better understanding of the impact EVA can have on the price reduction roadmap for the PV modules.

## Background and trends

The PV industry and its suppliers continue to expect a major growth in the next ten years and beyond, 20 to 30% a year, but very significant changes also are under way, mainly:

**There is a structural shift from a subsidized industry to a competitive one**, which offers additional growth, but also puts more pressure on the PV industry and its suppliers to produce increasingly cheap and efficient PV panels.

**There is a regional shift** from developed countries, Western Europe mainly, Germany and Italy, to Asia, where established PV producers are already in a strong position to capture a large portion of the expected growth, with corresponding changes in supply patterns for the chemical industry.

Solar module production was largest in Europe, where installations still are government subsidized, and is now dominant in Asia, where many new module plants are being built. Established Chinese players already dominate their growing domestic market.

On the longer range, to ten years, a **tremendous growth is expected** in the “sun-belt” countries, latitudes 35° N to 35° S.

**The technology shift to thin-film**, from the long established crystalline silicon, is creating a greater demand for PV-related chemicals. Thin film could reach a 25% market share of new installations by 2015, and a 35% market share by 2030, or earlier. It was less than 10% in 2007. The U.S. is ahead in building plants for the new thin-film cells, which can be built into both flexible and rigid solar modules.

**The long term objective of grid parity**, PV electricity price competitive with standard distributed electricity, could be achieved by 2018-2020, even though not yet everywhere.

## Study objectives

The objectives were to understand the cost structure of raw material components, capital cost and film/sheet processing cost. The client wanted to understand the factors that impact cost to anticipate future change as well as gain an understanding of regional variations, such as production in China versus more developed countries. A key issue was a quantification of film/sheet converters minimum margin expectations and price.

The cost analysis had to detail the product formulation, cost of raw materials and film processing cost.

EVA resin photovoltaic grades typically have a vinyl acetate co-monomer content of 33% and a melt index of 30. These grades are challenging to manufacture.

Product formulations include EVA resin, with the appropriate level of vinyl-acetate, cross-linking agents (peroxides), adhesive promoters (silanes), UV stabilizers, antioxidants, anti yellowing agents, important to guarantee the long lifetime of the modules, and any other critical ingredients.

The EVA compounded resins are extruded into films at low temperature, at variable thicknesses ranging from 300 to 600 µ (microns). The apparently most often mentioned thickness is 400-450 µ.

During the construction of the solar panel, the parts are heated up to about 150°C in order to initiate the cross linking process. At the same time the panel is carefully pressed under vacuum. The encapsulation protects the highly fragile silicon photovoltaic cells from breaking, from humidity. The encapsulant film also ensures the electrical insulation.

The raw EVA resin suppliers, the compounders, the film extruders, the extrusion machine manufacturers, the module manufacturers who use the films, are all amazingly discrete about the composition, the particular “recipes” of which the EVA encapsulants are made.

As a rule, the encapsulant film extrusion is an entirely distinct industry from the PV module or thin film manufacture. It would not be reasonable for a PV module maker to go outside his business and play around with film extruding. They always buy the films readymade.

The EVA encapsulant films are in long developed countries, Europe, US and Japan, so far, and the modules are in Asia, mainly China.

The consensus is that there is no trend to change from EVA to other materials or encapsulation. EVA is not very expensive and it is very well known and practiced. It has been used for a long time, and there would be no interest in changing, even though there is very active research everywhere for new materials.

There still are few materials competing with EVA for encapsulating films.

At the moment, the share of materials for the encapsulants is:
EVA 90-95%
PVB 3-5%
Then there are others, ionomers, new developments, TPU, PVF Tedlar

Some contacts commented that there will be a breakthrough for silicones, even though the liquid silicone experience was not so good. EVA is to stay here for the foreseeable future, at least a few years.

There is a growing competition from PVB, but it is more expensive. EVA is well-known and the adhesion to glass is good.

There are new module plants being built in Asia, in China, but they are often initiated by the large European manufacturers, either as direct investments, or joint ventures, or even toll production, with dedicated lines for the supply of the European players.

The general conclusion is that the photovoltaics, even though over twenty years old, truly commercial for less than seven years, still are at an early stage of development, as it seems the sky is truly the limit, in more exponential growth, in many innovations to come, in close to grid parity, thanks to continuing cost reductions. This is a new industry, with more promises than disappointments.

## Costs and pricing

As a rule, the encapsulant manufacturers express the film figures in tons or in m². The module manufacturers express figures in MW. In other words, the raw materials are expressed in tons, the film encapsulants are expressed in m², and the modules are expressed in watts.

*“A convenient rule of thumb is to use 140 watts per m². This average yield is the most important. The yield is 140 MW equal 1 million of m².”*

The EVA films used for encapsulation generally are 400-600 microns thin, for the C silicon, and about the same, maybe slightly thinner for encapsulation of thin PV films. One MW installed requires 7 tons of film, and 1 kg of encapsulant film is equivalent to 2.45 m².

*“As a rule, the film used for encapsulants of polycrystalline is 450 micron thick, put above, under and around. In thin film modules, the encapsulant is 600 micron thick, on one side.”*

In general, the most frequent fixed width for the reels is about 1 meter, or 90-95 cm. The module manufacturers will cut the reels to the length of the sheets they want. Sometimes, module manufacturers will want cut sheets, and not necessarily the smallest players. They purchase the sheets on pallets, all pre-cut and ready to process.

The encapsulants, films and sheets, go through a certification process, with an organization that tests the full module, the cell power, the output, the longevity of the encapsulant, as a module package. The testing organizations are separate for Europe, the US, Canada, etc., and by country for the rest of the world.

The fast growing demand in photovoltaics in the last few years has resulted in more production, prices have gone down, and still are going down.

There now are a few encapsulant film producers in Asia, with prices slightly less, trying to work more on mass than on margins, but their impact is not really felt by large well established encapsulant suppliers.

It is true that, with subsidies going down in all countries, the price of modules has to decrease. This price decrease is also linked to some extent to the new supply of new comers.

Each module manufacturer looks to lower costs. And, with a general cost decrease, all the components must go down, even encapsulants that are not a large percent of the total cost.

However, there is a strong core of the well established large suppliers of modules and encapsulants, who are not so much oriented to this price decrease, and prefer to continue competing on quality, performances, reputation, experience, follow-up. Large well-known European module manufacturers did not reduce prices much. Often they do not mind seeing their sales volume stagnant, or not growing fast, as long as they continue on their reputation and markets.

At the time of the study, roughly, the average price for encapsulant films was 2.5 Euros per m². Even if this sounds expensive, this is a specialty product, in which there are many in-house additives. The films are not easy to recycle as new scrap in the plants. The anti UV properties and other additives last less than six months in storage, and then they deteriorate. The large module manufacturers must have warehouses that are regularly supplied, not really in just-in-time mode, but say about every three months.

The price for encapsulants by the Asian encapsulant suppliers may be as low as 1.9 Euro per m², but it is not necessarily competitive with the larger supplier prices, with better image and properties.

The encapsulant prices were higher back in 2008, about 3 Euros per m², but this applied to lower tonnage then.

Every supplier proposes new formulas with the only objective to reduce the costs.

The process chain includes first the film extrusion, but this is a very specific film extrusion, as it is nothing like the extrusion for film bags. There are specific parameters that are carefully protected, as they are very strategic to the key issue of cost reduction. This explains the very reluctance of all film makers, and even the players down the chain, to reveal much.

Then, the module producers do the film lamination. One important objective is to reduce the energy cost in the fabrication of the module, in various ways, by shortening the processing time, decreasing the temperature. There are many savings to be perfected in this field, also considered as confidential knowhow.

Improvements in EVA crosslinking and extrusion capabilities continue to be researched everywhere.

**The very composition of the compounded EVA films**, with all the required additives, is also a well guarded secret. Either it is claimed to be quite secret, or the respondents pretend not to know, which may sometimes be true.

Every film manufacturer has his own recipes, and is not ready to divulge them. The recipes may vary for the various films, for different customers and there may be five or six different recipes for one customer. Each film has to be certificated.

The whole topic is very complex, because players are reluctant to talk, and because it is true that there are many possible solutions, often custom-made at the request of each customer.

## Photovoltaic industry structure

The process chain, and the players along, are the EVA plastic producers, compounders sometimes in-between, film extruders, module and panel manufacturers and assemblers.

**EVA films and other resin raw material suppliers**

The main resin suppliers for encapsulant films in the PV industry are relatively few. The main EVA PV encapsulant film manufacturers are, in alphabetical order:

Arkema, France, with Evatane 33-45PV, high content EVA specifically developed for PV solar panels

Bridgestone, Japan

Dai Nippon Printing Co., DNP CVF1, polyolefin encapsulants mainly for uses with crystalline silicon PV

Dow Chemical with the new Enlight, new encapsulant films suitable for C-Si and thin-film modules

DuPont, with a wide range of encapsulants, for traditional and thin film module design, with Elvax PV EVA resins, PV5200 Series encapsulant sheets based on PVB, PV5300 Series ionomer-based encapsulant sheets, Tedlar PVF film back sheets for solar panels. New sheets are made from polymer ethylene methyl methacrylate (EMMA).

ExxonMobil, Escorene Ultra EVA copolymer resins for photovoltaic cells

Mitsui Chemicals Fabro expanding its EVA-based solar film capacity to 20 000 tonnes from 9 000 tonnes in two phases

Solutia having acquired Etimex, and aiming full range supply, with Vistasolar EVA encapsulant, Saflex PVB, thermoplastic polyurethane, TPU, films. Solutia produce both EVA and PVB at Suzhou, China

STR, Specialized Technology Resources, Germany

However, besides the film manufacturers, there are many re-sellers, for instance in Germany, and even more in China. There also are Chinese disguised as Germans, and German working with new plants in China. The supply chain is very fragmented and not at all stabilized yet. The Chinese have begun extrusion of these films, reportedly with lower levels of vinyl acetate VA, say 28 %. There even is a rumor about 24 % EVA contents.

**According to the Berlin Institute**, film companies are investing their new plants in China, like STR. It is not for the cheap labor, because the impact of labor cost is not very high, it is more to be close to the module manufacturers.

Integrated supply chains from resin to film may give DuPont, Arkema and Mitsui an advantage.

**Photovoltaic modules**

According to an annual market survey by the photovoltaics trade publication *Photon International*, global production of photovoltaic cells and modules in 2009 was 12.3 Gigawatts, GW. There are more up-to-date figures in the General sources listed at the end of this paper.

The top solar photovoltaic (PV) module suppliers accounted for almost 70% of global PV shipments in 2013, up from 58 % in end 2011. The main module makers are in approximate order of decreasing size:

Yingli Green Energy, China
First Solar, USA
Trina Solar, China
Jinko Solar, China
Renesola, China
Canadian Solar, Canada
Sharp Solar, Japan
Kyocera, Japan
Panasonic, Japan
SunPower, USA
Suntech, China
China Sunergy, China
Conergy, Germany
SolarWorld, Germany
REC Group, Renewable Energy Corporation, Norway
Hanwha Solar One, South Korea
JA Solar, China
Sungen Solar, China
Isofoton, Spain

In Europe, the module manufacturers are essentially in Germany and Spain, not so much in the US that grow, but more slowly.

All the large module manufacturers have started having affiliated companies in new country markets, California, Mexico, India, Morocco, etc.

There are new module plants being built in Asia, in China, but they are often initiated by the large European manufacturers, either as direct investments, or joint ventures, or even toll production, with dedicated lines for the supply of the European players.

The policy of the major European module manufacturers is to consolidate their plants in Europe as their core business, with a good control of their production costs. The Asian investments are for them more like an adjustment variable, to take care of peak demand when it happens. So the risk is actually in Asia. The European modules are of a consistent quality and performances, with the same specifications. The Asian delocalizations are there just to absorb the current uncertain market variations.

To summarize, modules used to be mainly made in Europe, in Germany, and the additional capacity was recently installed in Asia.

Then there are many smaller module manufacturers, who play in a different courtyard, and apparently do not interest very much the large encapsulant suppliers. Of course, this is the present picture. It may change in the short medium range, as more PV solar demand appears in Asia, in the US and in other countries outside Europe. Again the PV solar market is very, very volatile.

As a rule, the large module manufacturers, the serious ones with world activity, do not have more than 2 encapsulant film suppliers, 3 at the very most. This very limited number of suppliers insures that:

The certifications have been obtained and it is better not to change.
There is a reliable volume assured, even in case of shortage

The whole reciprocal business is safer for all parties.

The encapsulant supplier is ready for immediate help in case of any problems. Actually the encapsulant suppliers are more considered as partners.

Since the PV business is very volatile, the encapsulant film suppliers also prefer to have a smaller number of customers whom they follow closely and who become more partners than pure customers. The key points with the customer selection by the encapsulant producers are follow-up, direct support, exchanges of experience, trust. When the quantities happen to be limited, the encapsulant manufacturers do not want to sell on allocation.

## China growing share in the photovoltaic industry structure

When the PV modules manufacturers are integrated, they may control silicon ingot, wafers, cells, module lamination, systems, but hardly ever will extrude the encapsulant films. Or, they may make the cells and the modules, buying wafers, to make the cells.

As of 2011, when the study was made, more than 50% of the modules made in the world were made in China. The China share is soon going to be 70%, and may be 80% within the next five years.

The cells and modules production capacity were, as of end 2010:

China 50%
Europe 20%, but 30 % of modules,
Japan 10%
USA 5%

But this split is fast changing with always more manufacture in China.

There are many module manufacturers in the world, as the entry is not very difficult. A laminator costs no more than 300 000 €, even less. Small machines can be found for 50 000 €.

There may be 1 000 companies now making modules in China, and the lists found in sites such as Alibaba are quite impressive.

Besides the very large module manufacturers, new companies appear all the time. But the pattern is bound to become similar to the history of concentration that took place in the car industry or in the electronics industries in their earlier years. The photovoltaic industry is just very new.

**The question is raised, why has China become so important in solar module manufacture?**

The basic costs, like in all investments, are machine investment, labor, energy cost. Actually, labor is not more than 10% of total cost, so the major advantage of China is not crucial. Ten years ago, the labor cost was an argument, but now it no longer is.

There are at least three answers to this question of the massive Chinese entry into photovoltaics.

Currency exchange favoring worldwide exports, applicable to all Chinese industries at the moment
Cluster phenomenon, for know-how, transfer
Good, even though recent, Chinese tradition in electronics, simple products, but high tech.

The Chinese have been most active in these consumer high tech applications, and the PV industry is just continuing. It was recognized as early as 2000 that the PV industry fits into this trend of Chinese development. Some Chinese producers have become good in PV, with innovations and patent pending.

To summarize, as of now, it can be said that the films are in developed countries, so far, and the modules in China. But the Chinese also start making films, like Hangzhou Sun for instance, but they are still in minority.

Yet the PV industry is very volatile and fast changing. China could become even more predominant.

## Perspectives for the photovoltaic industries

In this very volatile situation and outlook, the optimism about the PV industry development remains strong. Here are just some new reports found in early 2011.

According to a report, January 2011, from IMS Research, a British consultant, new PV installations in the world grew by 130% in 2010, reaching 17.5 GW, in line with earlier forecasts from IMS. IMS forecasts now indicate that there will be an additional over 20 GW in 2011, bringing the total PV installed capacity to 58 GW in the world by end 2011.

This IMS report identified at least 22 countries which each installed more than 50 MW in 2011, of which 18 countries to install at least 100 MW and 4 countries over 1 GW.

This report from IMS Research, revealed that only one of the five top markets, Italy, is in Europe, three are in Asia, showing the Europe decline in world share of PV.

China currently exports all but a small percentage of its solar panels, but is set to become a large user of solar power, with a goal to raise the share of renewable energy mix to 6% from the current 1.5%. In 2009, China Ministry of Finance launched a round of subsidies for large-scale solar projects as part of its “Golden Sun” initiative to boost solar power. China demand for EVA encapsulants is projected to almost triple by 2015 from its 2009 levels.

In 2010, Europe had 20 GW installed capacity, Japan 3 GW, USA 2 GW. China is now fast growing.

**According to the most recent study by EPIA, 2013**, the world cumulative solar photovoltaic (PV) electricity capacity surpassed 100 gigawatts (GW) in 2012, achieving just over 102 GW.

*“This global capacity to harness the power of the sun produces as much electricity energy in a year as 16 coal power plants or nuclear reactors of 1 GW each, enough to cover the annual power supply needs of over 30 million European households. Each year, the world PV installations reduce CO2 emissions by 53 million tons.*

*PV technology has grown over the past decade at a remarkable rate – even during difficult economic times – and is on the way to becoming a major source of power generation for the world. After record growth in 2011, the global PV market stabilized, with capacity additions in 2012 slightly above those achieved in 2011.*

*At the end of 2009, the world’s cumulative installed PV capacity was approaching 24 GW. One year later, it was 40.7 GW and at the end of 2011 it was 71.1 GW.*

*In 2012, more than 100 GW of PV are installed globally — an amount capable of producing at least 110 TWh of electricity every year. This energy volume is sufficient to cover the annual power supply needs of over 30 million European households.*

*Europe remains the world’s leading region in terms of cumulative installed capacity, with more than 70 GW as of 2012. This represents about 70% of the world’s cumulative PV capacity, compared to about 75% of the world’s capacity in 2011.*

*Next in the ranking are China (8.3 GW) and the USA (7.8 GW), followed by Japan (6.9 GW). Many of the markets outside EU – in particular China, the USA and Japan, but also Australia (2.4 GW) and India (1.2 GW) – have addressed only a very small part of their enormous potential; several countries from large Sunbelt regions like Africa, the Middle East, South East Asia and Latin America are on the brink of starting their development. Even so, the cumulative installed capacity outside Europe reached*

*30 GW as of 2012, demonstrating the ongoing rebalancing between Europe and the rest of the world and reflecting more closely the patterns in electricity consumption. The 200 GW mark could be reached in between 2014 and 2016, even up to 420 GW of PV systems connected to the grid by 2018".*

## General sources

### Magazines

Photon International, www.photon-magazine.com http://www.photon-international.com/

PV-Tech, http://www.pv-tech.org/

Sun, Wind & Energy, on renewables
Country specific versions available: Germany, Spain, Italy, www.sunwindenergy.com

Renewable Energy, www.renewableenergyworld.com

Enerzine, Interesting magazine in French on solar applications and other energies
http://www.enerzine.com/

Solarbuzz, a California based PV consultant and publisher, www.solarbuzz.com

### Universities and Institutes

**Fraunhofer Institut**, http://www.csp.fraunhofer.de/

The Fraunhofer CSP module is the technology center in Schkopau PV companies for joint applied research projects. The CSP combines the Fraunhofer Institute for Mechanics of Materials IWM and the Fraunhofer Institute for Solar Energy Systems ISE.

In cooperation with PV module manufacturers and suppliers the research projects are for development in the processing of new cell layouts, and for the production of alternative module developed techniques. The objective is to reduce the production cost and increase the module efficiency.

The Fraunhofer Center for Silicon Photovoltaics CSP is also the only center of its kind worldwide that analyzes the topics of crystallization and materials and carries out research and development into silicon materials.

**Berlin Photovoltaic Institute**, http://www.pi-berlin.com/

**EPUE Universities on energy** http://www.eua.be/eua-work-and-policy-area/research-and-innovation/Universities-Engaged-in-Energy-Research.aspx

Launching EPUE at the SET-PLAN Conference, Professor Torbjørn Digernes (Rector, Norwegian University of Science and Technology) announced that *"EPUE's main task is to provide a strong 'single' voice for Europe's universities in EU energy research by establishing a platform to facilitate the full participation of competitive European universities and their networks in achieving the goal of the SET-PLAN for a low carbon emission energy future".*

**EERA** http://www.eera-set.eu/

In October 2008, ten major National Research Institutes founded the European Energy Research Alliance (EERA).The key objective of EERA was to accelerate research on the development of new energy technologies by conceiving and implementing Joint Research Programs in support of the EU Strategic Energy Technology (SET) plan. The initiative seeks to pool resources, overcome fragmentation of research efforts and integrate activities by combining national and EU sources of funding, and maximizing complementarities and synergies through "joint programming" in identified priority research fields in energy. EUA, representing Europe's Universities, and EUROHORCS, representing Europe's major research funding and research performing agencies, were invited by the European Commission (DG Research) as observer members of the founding group of EERA.

**Solar Photovoltaic** (contact persons; wyers@ecn.nl; jeeninga@ecn.nl)
CEA, CIEMAT, CRES, ECN, ENEA, FhG-ISE, FhG-ISET, HGF-FZJ, HGF-HZB, IMEC, LNEG, Risø DTU, UK-ERC, Warsaw Univ. o. Technol

**INES Institut National Energie Solaire**, France, www.ines-solaire.fr general research on solar industry

**Poland Center of Photovoltaics**, http://pv.pl/ research, education on PV

**EPIA** (European Photovoltaic Industry Association), http://www.epia.org/home.html Main PV Association in Europe
Regularly published world forecasts
http://www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=/uploads/tx_epiapublications/GMO_2013_-_Final_PDF_01.pdf&t=1378289698&hash=5fa301e287d5f2b4cf33928ed79ed141bfa743fc

**Switzerland Paul Scherrer Institute**, www.psi.ch Dr. Philipp Dietrich

**Silicon Technology Development Unit, UDTS** for the initials in French, in Algiers, http://www.udts.dz/

**IMS Research**
http://www.imsresearch.com/index.php , a very large consultancy in electronics