BUILDING-INTEGRATED PHOTOVOLTAICS: AN EMERGING MARKET

EXECUTIVE SUMMARY

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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The segment of building-integrated photovoltaics is finally beginning to emerge in the marketplace after more than 20 years of R&D and fancy showcase projects, due to the vision of leading solar technology and material developers such as Dyesol, Schott Solar, Scheuten Solar, Sunpower, and Suntech.   Exciting new products that incorporate PV modules into actual building materials such as curtain walls, windows, and roofing shingles are now available from a variety of developers in the BIPV supply chain.

Earlier generations of PV for buildings utilized solar panels mounted directly onto the building roof with minimal aesthetic considerations.   This concept was replaced by building-integrated PV systems, where the PV modules actually came to replace parts of the building envelope, providing functional considerations and lowering costs.   More recently, thin-film PV technologies have begun to enable the seamless integration of PV onto buildings, and will likely succeed in markets where their superior flexibility, minimal weight, and improved ability to perform in variable lighting conditions gives them a significant competitive advantage over conventional solar technologies.

The success of creating new BIPV markets will depend on many variables, including:

1. Concerted efforts by players in the BIPV supply chain to work together towards the design and integration of solar into the building envelope;
2. Costs in $/Wp, as well as the building industry's preferred metric of $/m2, of product and power availability;
3. Development of specific standards and building codes;
4. Availability of federal and local incentives to ensure cost effectiveness;
5. Added value for consumers and architects; and
6. Ease of production and the scale at which a production plant becomes economically feasible.

For some time, thin-film solar technologies have not been at a price point to make them truly competitive with conventional solar-based panel systems that are just "slapped" onto buildings, but this is changing due to the current round of incentive schemes, and we expect that thin-film solar technologies will soon play a significant energy role in both the applications and the markets in which conventional solar materials are currently employed, as well as in markets where conventional solar materials are unsuitable for various reasons, such as façades, roofs and window applications.

There is some confusion regarding the definition of BIPV within both the PV industry and the building industry. We define BIPV as building-integrated PV, which requires that the building team along the entire supply chain -- including architects, building designers, engineers, building owners and utility companies -- work together to design and build the photovoltaics into the building's very "skin" as an element, from the inception of the project onwards. BAPV, on the other hand, is defined as building-applied PV. In this process, the photovoltaics are a retrofit, added to the building after construction is completed.

A number of factors limit the BIPV market. It is a clean technology that has been around for more than 20 years, and until recently, the market for this product was a relatively small and underdeveloped niche. BIPV manufacturers predominantly used mature but costly crystalline silicon-based systems, which were added to the building envelope retroactively and often performed poorly, especially in areas of minimal sunlight and/or high temperatures.

The development of thin-film flexible solar modules promises to be a major benefit to the BIPV market, since such modules will offer far better performance, as well as varying degrees of transparency and multiple color options. This will provide designers the opportunity to expand traditional architecture and transform buildings into aesthetically pleasing, energy-producing structures. However, several issues need to be resolved before the industry can advance to that point. Current obstacles include challenges such as optimal system orientation, weatherability, lifetime, the development of specific standards and building codes, as well as performance and cost-competitive pricing. In order to address these issues satisfactorily, all developers in the supply chain will need to work together to improve generating efficiency, as well as to reduce production and distribution costs.

As the cost of PV modules continues to fall, this will likely have an enormous knock-on effect towards the potential use of BIPV, since there is a need to maximize energy efficiency within the building's energy demand in order to optimize the entire energy system and costs. The demand for BIPV systems is expanding in the global construction materials market due to their reduced energy demands and overall reduced carbon footprint. In the years ahead, rising energy prices and the global focus on climate change will lead to an increased use of BIPV. The U.S. Department of Energy estimates that the development of BIPV products and their eventual deployment on the roofs and façades of commercial buildings and homes could generate up to 50% of the country's electricity needs. Thoughtfully developed feed-in tariffs need to be devised and implemented in the major solar markets to encourage the use of comparatively costly BIPV systems in both commercial and residential settings.

The BIPV market is poised to advance rapidly; however, GTM Research believes that in order for this to happen, the following critical questions first need to be answered:

Question 1: What are the barriers inhibiting market development and expansion?

In order for the BIPV market to achieve sizable growth and bridge the existing gap between the PV industry and the building industries, a number of key barriers must be addressed.

Technical barriers. New BIPV products that mirror the look and functionality of conventional primary building materials as a single integrated material require their own standards, and cannot rely upon existing PV and building product standards, since there are few if any performance-related standards that apply specifically to BIPV products, as Table E-1 shows. However, the major standards organizations around the world are working to change this situation. The introduction of E.U. Eurocodes and new standards from bodies such as International Electrotechnical Commission (IEC), Underwriters Laboratories (UL), and American Standards Test Method (ASTM) will address building materials, architectural, safety and electrical issues, as well as long-term performance issues. BIPV producers have developed their own standard-sized modules, which in some cases can cause structural overload of existing buildings, as BIPV modules can be quite heavy.

TABLE E-1: SUMMARY OF E.U. AND IEC STANDARDS FOR BIPV

SUMMARY OF E.U. AND IEC STANDARDS FOR BIPV						
Requirements	Mechanical resistance and stability	Safety in case of fire	Health, hygiene and environment	Safety in use	Protection against noise	Energy, economy and heat reduction
1. Components						
1.1 Modules	+	+	-	+	-	+/-
1.2 Inverters	+/-	-	-	+	-	-
1.3 Support structure	+/-	-	-	-	-	-
2. System	+	+	+/-	+/-	+/-	+/-
3. Installation	-	-	-	-	+/-	-
4. Maintenance	-	-	-	-	-	-

Source: EU modified by GTM Research

The state of California was one of the first states to develop a green building standards code, known as "CALGreen," which will mandate that new buildings in the state be more energy - and environmentally efficient. This code will also help the International Code Council develop the new International Green Construction Code (IGCC) for commercial buildings, which will be published in 2012.

Legal and administrative barriers. Until very recently, it was not possible to use BIPV on listed or historic buildings. BIPV is not yet defined as an energy-efficient technology in many jurisdictions, and as such, it is subject to an array of complex planning policies and procedures.

Market barriers. BIPV is still too costly, especially when compared with its rival technology, building-added PV (BAPV), since its added value as a multifunctional building element is only now beginning to be recognized. One issue that complicates the cooperation between the PV industry and the building sector is the fact that the two sectors use completely different units of measurement: architects and planners typically use kWh/m2, whereas the PV community routinely uses kWh/kWp. It turns out that many construction stakeholders and investors are not familiar with the concept of watt power, and would prefer to estimate the price of PV modules based on $\$/m^2$. For the moment, this is not such a straightforward process, since BIPV modules are not mass-produced, but are custom-built to order and therefore pricing varies significantly for each installation.

Perception barriers. The advantages of BIPV for architects and end-users are still not clearly defined, and some do not view the inherent aesthetic capabilities of the technology as a potentially valuable asset because they feel the underlying PV technology is outdated. This may be due to a lack of information on their part, or an outgrowth of the widely recognized fact that electricity consumption has come to play an increasingly important role in the value determination of buildings. In order for the BIPV market to grow, there needs to be greater acceptance from the construction sector and end-users alike, as well as a greater willingness to integrate PV from project inception through the entire construction process.

Question 2: What application areas look most promising for BIPV?

Aesthetics have long been a complaint of homeowners who are interested in switching to renewable power but were unhappy with the bulky look of conventional solar panels. Today, BIPV solar installations are able to serve as functional building materials in a number of applications, such as façades (cladding and curtain walls), roofing (solar tiles, slates, shingles and single-ply membranes), and windows (glazing, skylights and sunshades).

Given that BIPV use is so deeply intertwined with the construction industry, BIPV products are most cost-effective when used in new residential or commercial projects. The retrofitting of existing structures with BIPV products also benefits from this relationship, but represents a smaller growth opportunity. Advancing technologies such as CIGS, DSC, and OPV solar cells are able to offer almost invisible solar coverage; the emerging opportunities for these materials are summarized in Table E-2.

TABLE E-2: SOLAR TECHNOLOGY AND APPLICATIONS MATRIX FOR BIPV PRODUCTS

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SUPPLIER	PRODUCT	SOLAR TECHNOLOGY	APPLICATIONS	BENEFITS AND OUTLOOK
Applied Solar	SolarBlend™ tile	Monocrystalline silicon	Commercial flat and low-slope roofs	BIPV tiles integrate seamlessly with concrete tiles. Available now via Eagle Roofing Contractors.
Arch Aluminum & Glass	Active Solar Glass®	OPV	Semi-transparent glass BIPV products	50 percent visible light transmission. Commercialization from late 2010 in North America.
Ascent Solar	FlexPower Light™ Modules	CIGS	Façades and roofing	5 meters long and delivers 123 Wp (11.7% module efficiency).
Bluescope Steel	-	OPV	Metal roofing	Commercialization from 2011.
Corus	-	DSC	Metal roofing	Commercialization from 2011.
Dow Solar	PowerHouse™ solar shingle	CIGS	Roofing	15.54% efficiency. Commercialization from 2011, and estimates revenues of $5 billion by 2015.
Eagle Roofing	Eagle Solar Roof	Monocrystalline silicon	Commercial and residential roofing	Designed in collaboration with Suntech.
Heliatek GmbH	-	OPV	Façades and roofing	10% efficiency, cost $0.57 Wp. Commercialization from late 2010.
Lumeta Inc.	Solar S and Solar Flat tiles	Monocrystalline silicon	Commercial and residential sloped roofing	Solar S Tile simulates the shape of clay and concrete profiled tiles, resulting in greatly improved roof system functionality and aesthetics. Lumeta Solar Flat Tile integrates with conventional clay and concrete flat tiles, resulting in an aesthetically pleasing solar roof system. 28 Wp, and commercially available from mid-2010.
PowerFilm	PowerFilm laminate?	Amorphous Silicon	Metal and membrane roofing	5 percent efficiency and commercially available from early 2010.
Schott Solar	InDaX™ 225 module	Polycrystalline Silicon	Pitched roofs – new or retrofit	60 cells per module, which provides 210-230 Wp and 25 years warranty. Commercially available from March 2010.
Sharp	ND-62RU	Monocrystalline silicon	Roofing/façade	1 module replaces 5 standard concrete tiles.
Skyshades	Tension fabric	OPV	Shade on steel roofs	7.9% efficiency and commercialization during 2010.
Solarmer Energy	XPV™	OPV	Windows	45 percent transparency with 3 percent efficiency. Commercialization from 2011.
SRS Energy	Solé Power Title™	Amorphous Silicon	Roofing	Uses thermoplastic olefins.
Sunpower	Suntile	Monocrystalline silicon	Roofing	High-efficiency, roof-integrated solar tile blends seamlessly into flat and s-tile roofs.
Suntech Power	Just Roof™ LightThru™	Monocrystalline silicon	Residential roofing, Facades and windows	Replaces conventional roofing materials and provides a weatherproof roof surface. Installed base of more than 4000 systems in last 15 years.
Wurth Solar	STARfix III system, ARTLine Invisible system	CIS	Sloping roofs, Curtain wall facades	Systems use its GeneCIS modules commercialized in 2009. First company to offer colored CIS modules. Mainly in Europe.

Source: GTM Research

Despite a bright long-term outlook for BIPV, new construction starts and reroofing projects were slow during 2009 and into 2010. This has negatively impacted supplier sales, even for leading BAPV suppliers such as United Solar Ovonics through its traditional building-material channels. However, the economy will soon likely pick up and business will improve – provided that the construction industry picks up again and consumers start to come face-to-face with rising energy costs. According to the U.S. Congressional Budget Office, the number of housing starts in 2008 was 1.53 million, a figure that is expected to increase to 1.56 million in 2010 and then further expand to 1.58 million by 2012.

To counteract this decline, some suppliers (such as Sharp, Sunpower, and United Solar) have resorted to introducing new BAPV systems to the market, in order to expand near-term addressable markets beyond traditional BIPV. With this in mind, United Solar Ovonics recently launched a tilt BAPV product for rooftop retrofits, which leverages the lightweight attributes of BAPV's flexible amorphous silicon laminates, as well as a high energy yield that results in competitive levelized energy costs and attractive returns. The first wave of "new" thin-film products are due to hit the market in late 2010 or early 2011 from developers like Ascent, Odersun, Corus Colors, Dow Solar, and SKYShades.

Question 3: In which global regions will BIPV be most likely to succeed?

As expected, the best BIPV markets parallel the best markets for PV modules, as summarized in Table E-3. In Europe, the solar industry is largely dependent upon short- to mid-term government incentives, such as feed-in tariffs. Germany has been the primary driving force behind the growth of the global BIPV industry with its well-developed infrastructure, but this will likely change in the near future. Suppliers will have to refocus on other first-tier countries where the BIPV market is still small, such as France (which plans to increase solar significantly, with a particular focus on deploying BIPV for homes, schools and hospitals [€0.58/kWh]) and Italy (which is also placing emphasis on built-in PV, with tariffs for BIPV systems likely to receive 25% more than a non-BIPV equivalent project). In North America, BIPV is mostly concentrated in California, followed by New Jersey, with Ontario (Canada) also being a market that is expected to pick up in the near future.

TABLE E-3: COMPARISON OF THE MOST ATTRACTIVE FEED-IN TARIFFS FOR BIPV PROJECTS

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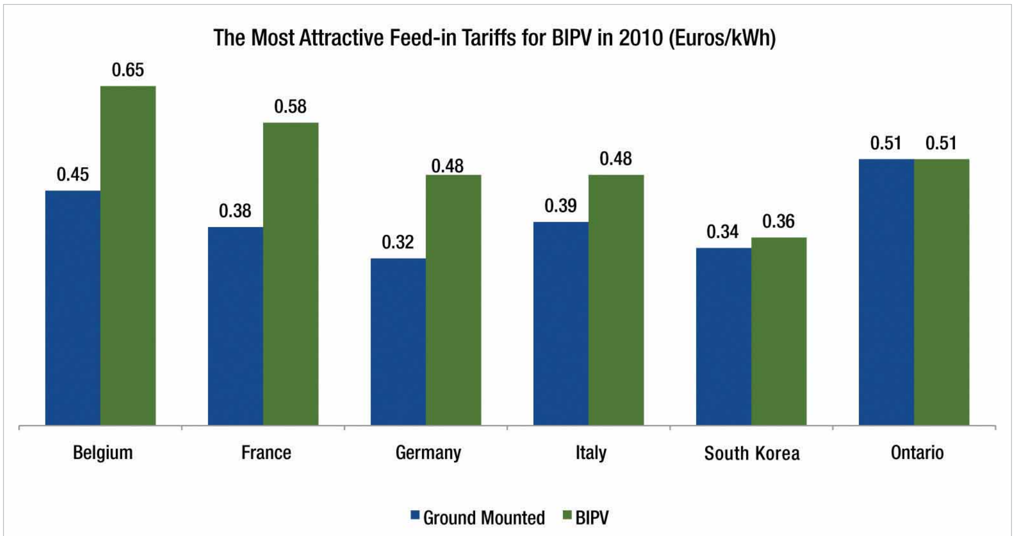
Region	North America		Europe			Asia
	California	Ontario	France	Germany	Italy	South Korea
Feed-in tariffs	0.23	0.26-0.51	0.42-0.58	0.33-0.43	0.43-0.48	0.27-0.36
€/kWh		Guaranteed for 20 years	Guaranteed for 20 years	Guaranteed for 20 years	Guaranteed for 20 years	Guaranteed for 20 years
Average Electricity Rates €kW/h	0.06-0.15	0.04-0.09	0.06-0.10	0.10-0.14	0.10-0.18	0.04-0.06
Solar Insolation Annual Average	5.4	3.44	3.34	2.98	4.21	4.16
kWh/m2/day	Los Angeles	Toronto	Paris	Munich	Rome	Seoul

Source: GTM Research

The feed-in tariffs shown in Figure E-1 represent some of the highest feed-in tariffs based on power output levels.

FIGURE E-1: THE MOST ATTRACTIVE FEED-IN TARIFFS FOR BIPV IN 2010 (EUROS/KWH)



Source: GTM Research

Second-tier countries that will likely develop BIPV markets include Belgium, Greece, Portugal, Switzerland, and Slovenia. All of these countries have favorable BIPV feed-in tariffs, which will incentivize market development to support significant growth by 2012.

To encourage the use of BIPV in Japan, the government is providing €410 million to resume its residential PV program, especially for small systems of less than 10 kW power (with a feed-in tariff of €0.39 kW/hr) and commercial programs (feed-in tariff of €0.20 kW/hr).

Question 4: Are low-efficiency solar technologies able to compete with high-efficiency solar technologies for typical BIPV applications?

BIPV is one of the fastest growing segments of the solar industry, especially in Europe, due in part to demand from architects, designers, and building developers. Until recently, aesthetic and performance concerns limited the ability of architects to use BIPV technology in their designs, but this is all changing with the emergence of energy-efficient and transparent solar materials that offer superior performance and multiple color options. With these features, BIPV will no longer need to be confined to spandrel or overhead applications using conventional silicon solar technology; rather, an entire building envelope can be put to use, allowing the structure to produce its own power using flexible thin-film materials (as shown in Table E-4).

TABLE E-4: COMPARISON OF PV CELL TECHNOLOGIES FOR THE BIPV MARKET

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Technology Segment	Crystalline Silicon	Thin Film					
	Mono	Multi	a-Si	CdTe	CIGS	DSC	OPV
Record cell efficiency	22 % SunPower	20.3%	12% United Solar Ovonics	12.4% EMPA	19.9% NREL	12% EPFL	7.9% Solarmer
Module ef-ficiency	13.5%	12%	6.5%	10%	11-12%	~5%	~5%
Cost S/Wp	$1.3-$1.8	$1.3-$1.8	$1-$1.6	$0.90	$1.5-$2	$3-4	$3-4
Energy pay-back time	<4.6 years	<2.7 years	9 years	1.1 years	<5.1 years	-	-
Stage	Commercial	Commercial	Commercial	Commercial	Introduction/ Scale-up	Development/ Introduction	Development/ Introduction

Source: GTM Research

Conventional solar technology made using crystalline silicon accounts for about 85 % of the solar market. As the most mature and widely used material for BIPV, most solar panels utilized for façades, curtain walls and roofs are made from this material. However, it is not necessarily the preferred material for building integration, even though its cost and performance are favorable, because of its aesthetics and a lack of flexibility.

Flexible thin-film solar materials, such as amorphous silicon, cadmium tellurium, CIGS, dye sensitized cells, and organic photovoltaics are far easier to use to integrate PV directly into architectural features such as building façades, roofs, and windows. These new materials offer a lower cost alternative as a function of the reduced material requirements and energy usage used in their manufacture as compared with conventional materials. Until recently, they could only be applied directly to building materials in a manner similar to the installation method used for most BAPV products, but can now be fully integrated into the material using other techniques such as low-cost printing or spraying. Builders appreciate the ease of working with rolls of such materials and they will no doubt come to be widely used, once a number of lingering technology and cost issues are resolved. It should be noted that BIPV is currently positioned as a very high-end building technology, but given its multifunctional nature and eventual plans for mass manufacture, its cost will likely come down.

Amorphous silicon is the most frequently installed thin-film material, with the majority of current capacity coming from United Solar Ovonics. Uni-Solar, the company's flexible 'peel and stick' amorphous silicon-based solar materials (BAPV), realizes module efficiencies up to 8%, and it is expected that third-generation technology could produce panels with 10% efficiency. CdTe promises higher efficiencies and lower costs than amorphous silicon, however -- competing firm First Solar's panels realized 11.1 % efficiency, and module cost was about $0.84 per watt by early 2010. Dow Solar's

CIGS-based solar tile product, due out in late 2010, is set to receive $140 million support from Michigan Economic Development Corporation, which is a huge endorsement of this technology platform, as well as for the evolving BIPV market as a whole.

Dyesol is taking a leading role in developing and commercializing building-integrated products based on dye-sensitized cell technology. The company's partnership with Corus Colors has reached the alpha model period, and this will ultimately lead to the commercialization of DSC-coated metal sheet for roofing applications by 2011. Dyesol has positioned itself well, creating subsidiaries in the major solar markets that are rife with buildings awaiting PV integration, including Germany, Italy, Japan, South Korea, the U.K., and the U.S.

OPV and BIPV look like an attractive match whereby large rolls of OPV could be placed on warehouse rooftops, a model that potentially represents a huge global market. In the United States, wooden roofs that cannot bear the load of silicon PV are commonplace, so architects using OPV would be able to provide added value to their customers. In Asia, Innovia Films and Bosch plan to join the Australian-based Victorian Organic Solar Cell Consortium this summer to help further develop and commercialize the group's OPV technology.