BIPV Glass Markets – 2012

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This report builds on the considerable amount of industry analysis that NanoMarkets has carried out in the BIPV, smart windows and related markets to provide an eight year forecast and roadmap for BIPV products.

This report examines and quantifies the market for BIPV products worldwide with coverage of both commercial and residential markets and a special consideration of the immediate market for BIPV in prestige buildings of various kinds. This analysis is carried out in the context of the latest developments in regional and national PV regulatory policy and construction industry trends.

The report also projects the development of BIPV glass systems themselves showing how they are expected to evolve from relatively crude systems with low levels of transparency to true integrations of PV and window glass. The report also looks at what the implications of all of this is in terms of opportunities for both PV and glass firms and assesses the current strategies of firms already pursuing the BIPV glass market. And as with all NanoMarkets reports, this report contains granular eight-year forecasts in both MW and dollar terms of BIPV glass markets, with breakouts by end user, type of product and type of PV technology.

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Chapter One: Introduction

1.1 Background to this Report

1.1.1 The Aesthetic and Cost Promise of BIPV

Building-integrated photovoltaics (BIPV) is one of the biggest hopes for turning PV into a substantial industry that might eventually be self-sustaining without government subsidies:

- By spreading costs across both the building energy system (or part of it anyway) *and* the building fabric, it becomes possible to create a new economics for PV that—at the very least—will increase the size of its addressable market.

- The improved aesthetics associated with BIPV is also another factor that NanoMarkets expects to grow the BIPV market. For those whose tastes are distinctly in the modern era of architecture (or perhaps in the post-modern era), the BIPV buildings that have been built to date would certainly also qualify as beautiful. Certainly they are in contrast to a large—and very visible—panel on a rooftop rack that might be considered ugly by many different tastes.

However, while BIPV may be the best hope for a PV industry that can survive without so much government largesse, this should not be taken to mean that the BIPV market is free from government influence. In particular, we see a growing role for BIPV to satisfy building codes that call for zero-energy buildings. BIPV may also be important in obtaining LEED certification.

In addition, it is perhaps worth mentioning that while direct subsidies for PV are under threat, there are too many of them, and they are too diverse, for them to disappear completely. And there are some subsidies that specifically apply to BIPV. Such special BIPV subsides are available in China, France and Italy. Germany had them, but they have gone now; perhaps this is a sign where the other BIPV subsidies are eventually headed.

1.1.2 Is Transparency a Selling Feature for BIPV?

Most BIPV products are not transparent, rather they are opaque products—principally siding and roofing products—into which PV functionality has been integrated in some way. Transparent BIPV products—by contrast—address a very different marketplace. These are used not for siding or roofing, but rather for skylights, spandrels, facades and shading structures.

But even such applications are in fact, only partially transparent and while they could not be addressed by other kinds of BIPV product, high levels of transparency in BIPV glass are not

achievable without a loss of efficiency and often an increase in cost. Nonetheless, transparency is the major factor that distinguishes the BIPV glass from other kinds of BIPV and, as a result, it will receive growing attention from BIPV glass firms, both as a way to compete against each other and against other forms of BIPV.

But the big question is whether improving BIPV glass in this way really makes that much difference in the sense that customers are really in search of transparency. If this is the case then product strategies aimed at improving transparency without too much cost in terms of either money or efficiency will be important. However, NanoMarkets believes that the jury is still out on this matter:

- On the one hand, it seems to be common sense that significantly more opportunities would arise, if BIPV glass would achieve a transparency that is much closer to that of window/vision glass, even though BIPV glass may never be chosen where one wants to provide visual access to some beautiful scene.

- On the other hand, many of the applications in which BIPV glass is currently used do not seem to be crying out for a lot more transparency. In any case, there are limits on what can be achieved in terms of transparency because PV panels are inherently absorbent. And while the sunlight could be transported from the window or other glass building material to a somewhat remote PV panel, this could not be done easily without lowering the efficiency of the panel or even maintaining a reasonable claim that the term "integrated" applies.

However, to better exploit the opportunities that *do* occur for BIPV glass firms to compete on transparency, we note that there currently appear to be three classes of product strategies:

- The standard strategy is to create BIPV glass panels by simply glazing together small opaque solar panels and window glass in a kind of mosaic; if the cells cover (say) 50 percent of a surface, then the BIPV glass panel will be 50 percent transparent. This has the advantage that it is a purely mechanical form of integration that can be accomplished through local glazing

- Special forms of optical devices can be deployed that enable BIPV glass panels to be built that are not blocked by PV cells. Pythagoras' prisms are the most obvious example of what could become a broader class of technologies

- Or newer, more transparent PV absorbent materials can be used. Most BIPV glass today uses crystalline silicon absorber layers which are inherently opaque. Better transparency

could be achieved at a reasonable level of efficiency using other absorber layers such as very thin layers of CIGS or dye sensitive cells

1.1.3 Glass and "BIPV Chic"

The proverbial bottom line then is that transparency is what makes BIPV glass unique in the PV space and there are ways that can make BIPV glass more transparent. But what there is not yet is any real proof that what the market wants is a lot more transparency. *So BIPV glass may have to fall back on competitive factors that it shares with other BIPV products to deal with competition and grow markets.* These lie largely in the areas of aesthetics and building economics.

Aesthetics may be especially important. We have already mentioned that BIPV is capable of providing some stunningly attractive buildings of a certain style and in our view, in a few cases at least, BIPV has been chosen for image reasons much more than on the grounds of economics, suggesting that it can contribute towards something we are calling "solar chic."

The architectural style embodied in most BIPV buildings very much reflects the fact that its basic building blocks are panels and, of course, where we are talking about BIPV glass, we are usually talking about a class of building in which at least part of the building uses a lot of glass panels.

The initial markets for BIPV glass are to be found in skylights, facades, curtain walls, and shade structures such as canopies. Increasing the likelihood that BIPV glass can be used to create attractive exteriors for buildings is the fact that BIPV glass can often be easily built to custom dimensions and shapes, either by adjusting the number and spacing of crystalline silicon cells or by cutting thin-film PV panels to size.

1.1.4 Future BIPV Glass Innovation Patterns

It seems likely to us that much of the innovation in the BIPV glass space in the immediate future is going to be concerned with aesthetic factors, for the reasons suggested above and the fact that such innovations may be reasonably easy to achieve. In addition, we can expect BIPV glass to benefit from positive developments in the PV space as a whole. For example, more transparent dyes being used in DSC-based PV, or thinner CIGS absorber layers seem likely to enhance the performance of BIPV glass, even though it is pretty obvious that these are happening primarily *in order* to build the BIPV glass business.

That said, there are some BIPV glass-specific innovations that we expect to see emerge during the next few years:

- Improvement in manufacturing platforms. Manufacturing facilities for integrated BIPV glass is, at the present time, mostly occurring on pilot lines with limited yields and profitability. Higher volume production is likely to occur – indeed is essential – if BIPV is going to move from its current limited focus on prestige buildings to more mainstream commercial buildings. In fact this evolution to larger plants is beginning to occur and economies of scale may prove a potent competitive factor in the BIPV glass business in the not too distant future.

- The second kind of innovation that we expect to see in the BIPV glass space is that the lines between BIPV glass and "smart" glass (or "smart" windows) will become fuzzier. Already there is considerable talk about about higher levels of functionality being integrated with BIPV glass.

  While, we think that this kind of development is quite a few years from reaching true commercialization, it would be surprising if some trial products of this more integrated kind did not appear during the period under consideration here. Some of the ideas that have been mentioned in the literature at one time or another include self-cleaning PV panels, panels that protect PV from degradation caused by heat from very bright sunlight, panels that collect solar energy during the day and become an OLED lighting panel at night, and panels that can shift between being a display and a PV panel.

Apart perhaps from the last mentioned of these possible products, there do seem to be good arguments that such products would find some real demand. For example, a self-cleaning PV panel may well repay the additional cost through greater energy conversion efficiency.

1.1.5 Bottom Lines on BIPV Glass

The ultimate goal for any kind of BIPV from an economic perspective is that it can lower the total cost of construction, because it is less expensive than the total cost of conventional building products and conventional PV. This is no less true of BIPV glass than it is of BIPV roofing or siding.

It is probably fair to say that this kind of economic calculation has not yet been proven, which may be why marketing for BIPV products, often puts so much emphasis on aesthetics rather than economics. For the BIPV market to establish itself, in the next few years we are going to need to see proof that this kind of economics can be established for BIPV. If costs for BIPV begin to reach the point where BIPV products can be positioned as part of a standard portfolio of high-end building materials, then we are talking about an entirely different value proposition for BIPV than currently exists and there is a chance that the demand for BIPV will explode.

Again, the above applies to all BIPV products, not just to BIPV glass. But some special factors play into the scenario for BIPV glass. These relate to the very high cost of the architectural glass around which BIPV glass panels are built:

- Because the cost of architectural glass so high, the economics of BIPV glass may become more favorable quicker than in other parts of the BIPV market. In other words, the additional cost of adding PV to architectural glass may be relatively modest compared with (say) adding it to wall cladding.

- Secondly, the high cost of architectural glass leads to high costs for BIPV glass. In NanoMarkets' forecasts, this translates into a large market in value terms for BIPV glass, even if the market in volume terms seems fairly modest; that is the number of BIPV glass projects around the world is not so large

Then finally, there is the whole question of the pricing of BIPV glass. This is yet another open question. At the current state of market evolution, where BIPV products are being sold primarily into the prestige building segment, we think that the market for BIPV glass is relatively price inelastic. However, this is unlikely to remain the case as BIPV glass becomes a bigger part of high-end "green" building products. Novel pricing strategies will then become the order of the day.

1.2 Objective and Scope of this Report

The goal of this report is to quantify and analyze the market opportunity for BIPV glass over the next eight years and it builds on industry analysis that NanoMarkets has carried out in the BIPV and smart windows business over the past few years. NanoMarkets has been covering the BIPV space now for more than four years and the PV space for a few years longer.

With regard to the scope of this report, we have included coverage of the use of BIPV glass in all end-user segments:

- We take those to include primarily commercial buildings and residential buildings (both single-family and multi-tenant), but we have also included a special section on the role of BIPV glass in "prestige buildings," a weakly defined category, but one where BIPV has found its first revenues.

- At the other end of the scale, we have also taken a look at possible uses for BIPV glass in the industrial end-user sector and have also included a section on "other" non-traditional sectors, such as in transportation.

We have also included in our coverage all the types of PV technology (that is, as characterized by the absorber layer) that are applicable to BIPV; which is most of them. For the purpose of this report, we have divided these PV technologies into three areas:

- Conventional (i.e., crystalline silicon),
- Thin-film (i.e., amorphous silicon, CdTe and CIGS)
- Those PV technologies based on organic materials (i.e., organic PV and dye sensitive cells).

Because of the specialist nature of this report, we do not discuss the general markets for these technologies to any great degree, we are primarily concerned with their role in BIPV glass. Each of these PV absorber layer technologies has a different role to play in the evolution of BIPV glass.

Our discussion of the evolution of BIPV glass also looks at the evolution of BIPV products themselves:

- Thus, at the present time much of what passes for BIPV glass is really just c-Si PV panels glazed in with window glass on site, which strains the definition of "integrated" somewhat. This report covers how this kind of integration will develop into something closer to monolithic integration along with possible end games in which smart windows and BIPV functionality merge to some degree.

- On the other hand, we have given only passing reference to what was once called "first-generation" BIPV, but is now more usually called building-attached PV (BAPV). In this approach, completely conventional PV panels were disguised by the architecture of a given building and it was this kind of disguise that constituted the "integration." BAPV is still very much alive but contrasts to a high degree with "true" BIPV, where the integration is of a technological rather than an architectural nature.

  We believe that BAPV may still legitimately be considered a sort of first-generation BIPV approach. But we don't see it as competitive with the advent of "second-generation" BIPV technologies that have been created specifically to serve building markets and are the real focus of this report.

This report is worldwide in its scope. However, throughout this report, we have discussed the differences between regional/national markets:

- One reason for that is that the PV industry as a whole is so focused into a few markets; Germany, Japan and California accounting for most of the entire worldwide market.

- Other reasons for focusing to some extent on regional national differences is that regulatory factors and conditions in the construction industry can vary quite a lot from place to place, not to mention taste/architectural factors of importance to the BIPV glass business. Obviously, space does not allow a full coverage of matters as complex as regulation and national construction markets. Rather, we try to point out the impact of general trends.

Although as with all PV, the economics of including BIPV glass in buildings are better with new construction than with retrofits, but we discuss both opportunities in the main body of this report.

The report also looks at what the implications of all of this is in terms of opportunities for both PV and glass firms and assesses the current strategies of firms already pursuing the BIPV glass market. And as with all NanoMarkets reports, this report contains granular eight-year forecasts in both MW and dollar terms of BIPV glass markets, with breakouts by end user, type of product and type of PV technology.

1.3 Methodology of this Report

The information for this work is derived from a variety of sources, but comes from both primary and secondary sources:

- As far as the former goes, NanoMarkets has carried out extensive interviewing of business development managers and technologists involved with the BIPV market generally and the BIPV glass in particular. These interviews have been carried out as part of NanoMarkets' ongoing interview program for its PV and BIPV markets research projects.

  But, in addition, we have also carried out special interviews designed for collecting information specifically for this report and obtaining more granular information on BIPV glass in particular.

- As with other NanoMarkets reports, we have also drawn on important secondary resources for information. These include technical literature, relevant company Web sites, trade journals, government resources, and various collateral items from trade shows and conferences.

Some of material in this report has also been taken from earlier NanoMarkets reports including our reports on PV, BIPV, smart windows and (to a limited extent) we have also taken it from some of our OLED lighting and glass industry reports in other words from NanoMarkets reports that address advanced building materials in one form or another. However, where information has been used from an earlier report, it has been reinvestigated, reanalyzed, and reconsidered in light of current developments and updated accordingly.

The forecasting approach taken in this report is explained in more detail in Chapter Four, but the basic approach taken here is to identify and quantify the underlying needs and markets that are served by BIPV glass products; consider the specifics of the applications and the types of products available or under development; and assess the competitive landscape to determine the suitability and likely volume of each of the BIPV types over the next eight years. The stated plans of the key firms are of course of special interest, although NanoMarkets critically considers these claims in light of all available data.

1.4 Plan of this Report

Chapter Two of this report focuses on BIPV glass technologies and products and to some extent some of the firms that manufacture them today. This chapter includes a broad discussion of the economics and aesthetics of BIPV glass, as well as an assessment of how the various PV absorber materials are likely to find opportunities in the BIPV glass market. This chapter also explores potential revenue generation from the merging of the BIPV glass and smart windows sector. This chapter also takes a look at the commercial potential for retrofitting and customization, along with potential for substituting other transparent materials for glass in transparent PV.

In Chapter Three we explore the demand side of the BIPV glass market by analyzing the overall dynamics of global building and PV markets and reviewing the differing expectations of architects, builders, and roofers. The core of this chapter, however, is an analysis of the various sectors into which NanoMarkets sees BIPV glass being sold. These were listed above and include commercial and residential buildings, but with special attention being given to the "prestige building" sector into which NanoMarkets expects there to be significant early sales of BIPV glass.

Finally, Chapter Four contains our eight-year forecasts of the markets for BIPV glass. The chapter comprises a detailed discussion of forecasting methodology, sources of information, pricing assumptions and also provides some alternative scenarios. The breakouts of the

forecast are by end user, type of PV used and the type of BIPV glass product. Forecasts are provided in both volume (MW) and revenue ($ millions) form.