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PV and PV/Hybrid Products for Buildings

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ABSTRACT: Residential, commercial, and industrial buildings combined are the largest consumers of electricity in the United States and represent a significant opportunity for photovoltaic (PV) and PV/hybrid systems. The U.S. Department of Energy (DOE) is conducting a phased research and product development program, Building Opportunities in the United States for Photovoltaics (PV:BONUS), focused on this market sector. The purpose of the program is to develop technologies and foster business arrangements integrating cost-effective PV or hybrid products into buildings. The first phase was completed in 1996 and a second solicitation, PV:BONUS2, was initiated during 1997. These projects are resulting in a variety of building-integrated products. This paper summarizes the recent progress of the seven firms and collaborative teams currently participating in PV:BONUS2 and outlines planned work for the final phase of their work.
Keywords: Building Integration - 1: PV System - 2: Manufacturing and Processing -3.

1. INTRODUCTION

The buildings sector in the United States requires nearly one-third of the nation's total annual energy budget. This sector also consumes about two-thirds of the total annual electricity production (Figure 1) [1]. Because this sector has a large portion of the market, improvements to reduce conventional energy demands can have a significant effect. PV and other renewable approaches can be incorporated into building products to reduce this demand.

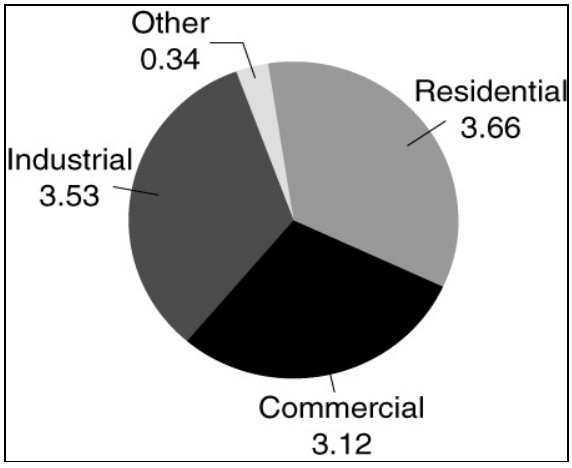

Figure 1. Illustration of 1997 electricity end-use flow in quadrillion Btu [1]

To address the opportunity, the U.S. Department of Energy (DOE) initiated a program, Building Opportunities in the United States for PV (PV:BONUS), in 1993. The goal is to develop new and innovative PV and PV/hybrid product concepts. Program objectives are to develop technologies and foster business arrangements to cost-effectively integrate PV or hybrid products into buildings. An important factor is that these products must be installed without the need for specialized training.

The PV:BONUS program has consisted of two solicitations. The first solicitation, PV:BONUS, was completed in 1996, with total government funding of $7.9 million. The five industry partners selected for PV:BONUS committed a total of $9.0 million. The results from this work are described in a previous paper [2].

The second solicitation, PV:BONUS2, is a five-year program now in the second of three planned phases of development. Cooperative agreements were negotiated with successful bidders to initiate Phase 1, "Concept Development and Business Planning." Prototype systems were developed and tested in Phase 2, the "Product and Business Development" stage. The final phase is "Product Demonstration and Marketing," when commercially viable products are expected. Only those manufacturers successful in Phase 1 could compete in Phase 2, and these results, along with plans for Phase 3, formed the basis for selecting which manufacturers receive support for Phase 3. Through Phase 2, DOE funding for PV:BONUS2 totals $6.6 million. Phase 1 required a 20% cost share, and Phase 2 required a minimum of 50% cost share. This paper reviews the PV:BONUS2 progress to date.

2. BUILDING OPPORTUNITIES IN THE U.S. FOR PV -- PHASE 2 (PV:BONUS2)

PV:BONUS2 was initiated during 1997 with Phase 1. Through competitive selection, 17 firms participated. This phase included tasks to develop a product concept; product manufacturing or fabrication and installation cost estimates; business planning; and a market assessment for the proposed product, including target selling prices, target market sectors, size estimates for each market sector, and planned distribution mechanisms for market penetration. Each participant had about 9 months to complete this phase.

Table 1: List of PV:BONUS2 firms and teams, topics of their work, and participation by Phase.

Company	Topic	PV:BONUS2 - Phase 1	PV:BONUS2 -Phase 2	PV:BONUS2 -Phase 3
1. Advanced Energy, Inc.	PV string inverters	✔	✔	
2. Ascension Technology, Inc.	Ballasted PV arrays	✔	✔	
3. AstroPower, Inc.	PV/glazing design	✔		
4. BP Solarex	PV/lighting (3 BIPV products)	✔	✔	✔
5. Delmarva Power & Light Co.	AC PV modules	✔		
6. Energy Conversion Devices, Inc.	PV/thermal solar metal roofing System	✔		
7. Kiss + Cathcart, Architects	Patterning system for thin-film PV	✔		
8. Evergreen Solar, Inc.	PV with flashing	✔		
9. Global Solar Energy, LLC	Flexible CIGS PV films	✔		
10. Omnion Power Engineering Corp.	Uninterruptible Power Supply/PV	✔		
11. PowerLight Corp.	PV roofing with insulation	✔	✔	✔
12. Sage Electrochromics	PV electrochromic windows	✔	✔	✔
13. Solar Design Associates, Inc.	PV/thermal hybrid	✔	✔	✔
14. Springborn Testing & Research, Inc.	Flame-retardant PV encapsulant	✔		
15. TerraSun LLC	Transparent PV	✔		
16. United Solar Systems Corp.	Field-applied PV roof membrane	✔	✔	✔
17. United Solar Technologies, Inc.	Dish concentrator	✔		

2.1 Phase 1 - Concept Development and Business Planning

Table 1 lists the 17 companies, along with project titles, that participated in Phase 1 of PV:BONUS2. Only the lead proposer is listed, but several projects are a team effort.

2.2 Phase 2 - Product and Business Development

The second phase of PV:BONUS2 was initiated during 1998. This phase includes detailed product development, test plan development, fabrication and testing of pre-production prototypes and components; system-level design; system-level testing in cooperation with the National Renewable Energy Laboratory (NREL) and/or Sandia National Laboratories; commercial team development; and further refinement of a business and marketing plan. Additionally, Phase 2 includes development of a test and acceptance plan for the commercial product and development of a production plan for demonstration and market entry. Of the 17 companies eligible to participate from Phase 1, 7 were competitively selected for Phase 2. Table 1 indicates these participants. Descriptions of their accomplishments follow, listed in alphabetical order of company.

Advanced Energy, Inc., refined the design of their 1-kW grid-interactive PV inverter, the GC-1000. This unit integrates the string combiner, AC and DC disconnect, and DC ground-fault detector into one unit. During this phase, the unit received an Underwriters Laboratories (UL) listing, and units are being installed through a market arrangement with panel manufacturers, system integrators, and PV dealers throughout the United States. Models meeting European specifications will be available soon.

Ascension Technology, Inc., Division of Applied Power Corp. (APC), refined the design of their ballast-mounting for PV arrays to eliminate possible movement of their zero-penetration mounting approach under high winds. Computer analysis and physical testing confirmed design changes. The improved approach was demonstrated in a 4-kW school system and is now part of the standard installation method.

BP Solarex teamed with Kawaneer, Solar Design Associates, and Viracon to develop building-integrated PV (BIPV) products using tandem-junction a-Si PV modules. These products include an opaque spandrel curtain wall, an insulated viewglass window termed PowerView (Figure 2), and a power sunshade. Recent accomplishments include

cutting the coated glass using a water-jet approach and heat-strengthening the glass after processing. This team has also developed analysis software to assist customers in determining the expected benefits from these products.

The fourth company in this group, *PowerLight Corporation*, is working to complete development of two products. HeatGuard™ is an interlocking, insulating roof tile

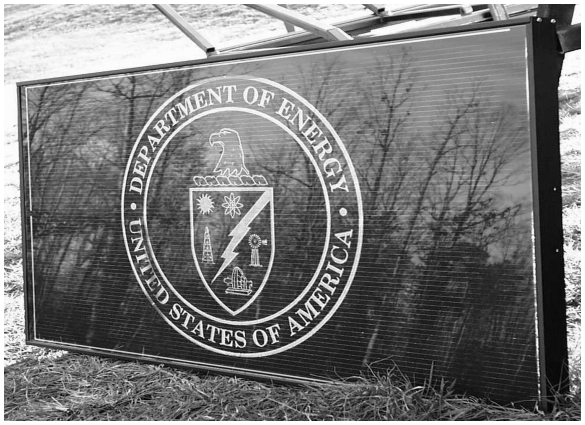

Figure 2: Prototype BP Solarex PowerView, an insulated viewglass window developed in PV:BONUS2.

that allows only 1% of the thermal insolation into the building. Tests of HeatGuard™ compared to other roofing materials illustrate a significant cost savings. PowerLight is also developing a combined PV/thermal hybrid system, termed PowerTherm™. This medium-temperature system is designed for commercial domestic hot-water loads and desiccant refrigeration. This combined solar thermal and PV product uses an amorphous silicon (a-Si) PV module as the front surface and is illustrated in Figure 3.

Sage Electrochromics, with team members BP Solarex, Viracon, and Libbey-Owens-Ford, is working to develop PV-powered electrochromic (EC) windows. During Phase 2, Sage

Figure 3: The PowerTherm™ combines solar thermal and PV electric power

established a pilot facility at the Viracon glass-coating plant, developed a variable control for the PV-powered EC window, and simplified the design. Skylight-sized substrates that are 4.8 cm x 99 cm (19-in. x 39-in.) have been processed in the new pilot line.

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Solar Design Associates (SDA) is working with United Solar Systems Corp. (USSC) and SunEarth Inc. to develop a hybrid PV/thermal product, called Phototherm. It is a unitized combination of a liquid thermal collector and the USSC triple-junction a-Si thin-film module. Phototherm resembles a traditional solar thermal design, except that the PV module replaces the top surface of the absorber plate. The current Phototherm product is designed for installation on an existing rooftop. A BIPV product is under development and will be demonstrated at the EPI Center Building planned for construction at the University of Montana in 2001.

The objective of *United Solar Systems Corp. (USSC)* effort is to develop a field-applied, flexible PV membrane (PVM) based on their a-Si production stainless steel. During Phase 2, they completed the product design, fabricated prototypes, and developed a "peel and seal" method for applying the PVM to roofs. The product also received UL listing. Outdoor performance testing is under way.

Figure 4: Prototype Phototherm product adjacent to thermal-only collector on test.

3. PHASE 3 PLANS FOR PV:BONUS2

Of the seven firms participating in Phase 2, five are continuing work under Phase 3 of the PV:BONUS2 program, as indicated in Table 1. Two projects were not continued, as a result of funding constraints. *BP Solarex* is working to improve its fabrication of heat-strengthened glass and to develop a UL-recognized edge-connector for the PowerView product. *PowerLight* will complete testing of the production prototype of their PowerTherm™ PV-hybrid product. They will also fabricate HeatGuard™ tiles and verify the projected energy savings. *Sage* plans to enhance the performance of the EC windows and to continue developing their PV-powered automatic controls to manage transmitted light. Sage's pilot line is planned for full operation by the end of the year. *SDA* and its team will continue testing the Phototherm PV/hybrid product, to finalize the design for installation in 2001. During it final Phase, *USSC* will establish their mass production line for the PVM, conduct production test runs, and begin installation at demonstration sites. By the end of 2000, the five teams will have defined demonstration projects for their products at several locations. All work in Phase 3 is expected to be completed by the end of 2001.

4. SUMMARY

Building designers want PV systems that can be integrated into the building envelope and blend well with other building-related components and materials. Many of the products currently being developed through the PV:BONUS2 program meet these criteria. These products are planned to be on the market during 2000. They are expected to reduce building demands for conventional energy and to meet architectural and building-code requirements.

5. ACKNOWLEDGMENTS

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