

PV Manufacturing R&D Project— Trends in the U.S. PV Industry

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ABSTRACT

To foster continued growth in the U.S. photovoltaic (PV) industry, the U.S. Department of Energy initiated the PV Manufacturing R&D (PVMR&D) Project—a partnership with U.S. PV industry participants to perform cost-shared manufacturing research and development. Throughout FY 2004, PVMR&D managed fourteen subcontracts across the industry. The impact of PVMR&D is quantified by reductions in direct module manufacturing costs, scale-up of existing PV production capacity, and accrual of cost savings to the public and industry. An analysis of public and industry investment shows that both recaptured funds by mid-1998 based on estimated manufacturing cost savings from PVMR&D participation. Since project inception, total PV manufacturing capacity has increased from 14 MW to 201 MW at the close of 2003, while direct manufacturing costs declined from \$5.55/W to \$2.49/W. These results demonstrate continued progress toward the overriding goals of the PVMR&D project.

1. Objectives

PVMR&D is a research and development partnership between the U.S. Department of Energy (DOE) and members of the U.S. PV industry. It is designed to: (i) help U.S. industry improve PV manufacturing processes and equipment; (ii) accelerate manufacturing cost reductions for PV modules, balance-of-systems components, and integrated systems; (iii) increase commercial product performance and reliability; (iv) and enhance the investment opportunities for substantially scaling up U.S. manufacturing capacity and increasing U.S. market share. PVMR&D procurements are framed to specifically address milestones under the Solar Energy Technologies Program Multi-Year Technical Plan, as shown below in Table 1.

Table 1: PVMR&D-related PV Subprogram milestones

Milestones for Flat-Plate PV Subprogram	
Task I.3 Milestone 14: Reduce direct module-manufacturing costs to \$1.75 and achieve module-manufacturing processes capable of \$1.50/watt direct module-manufacturing costs with 500-megawatt production capacity	CY 2006
Task I.6 Milestone 25: Complete development (achieve manufacturing-line-ready status) for at least three in-line diagnostic processes initiated in FY 2002 awards from In-Line Diagnostics, Intelligent Processing Solicitation	CY 2005

Under the continuing “In-Line Diagnostics and Intelligent Processing” (IDIP) procurement, PVMR&D focuses on integrating state-of-the-art process controls with current

production technology in support of Task I.3 Milestone 14 and Task I.6 Milestone 25.

The focus of the upcoming subcontracts under the FY 2003 procurement, “PV Manufacturing R&D—Large-Scale Module and Component Yield, Durability, and Reliability” (YDR), will be on enhancing field reliability and durability, as well as manufacturing yield. Work efforts under this procurement will be in support of Task I.3 Milestone 14.

2. Technical Approach

PVMR&D partners with members of the U.S. PV industry through cost-shared subcontracts, selected through a competitive solicitation, in order to bolster manufacturing efforts within U.S. borders. Subcontracts under this project have focused on three areas: (i) module manufacturing; (ii) balance-of-system components and systems integration; and (iii) industry-wide applications.

3. Results and Accomplishments

3.1 PVMR&D Project Impact

To measure progress toward program milestones, PVMR&D, in collaboration with industry partners, compiles and analyzes a database of historical and projected values for manufacturing cost and capacity figures, as well as estimated cost savings directly related to project participation. Evaluation of this data shows demonstrable progress toward achieving the cost goals as outlined in Task I.3 Milestone 14.

Figure 1 shows the cost-capacity results of the 2003 survey of PV module manufacturers. Total PV manufacturing capacity has increased from 14 MW at the project’s inception to 201 MW at the close of 2003. This increase in capacity represents a 25% compound annual growth rate over the twelve-year period examined. Direct manufacturing costs, in 2003 constant dollars, declined from

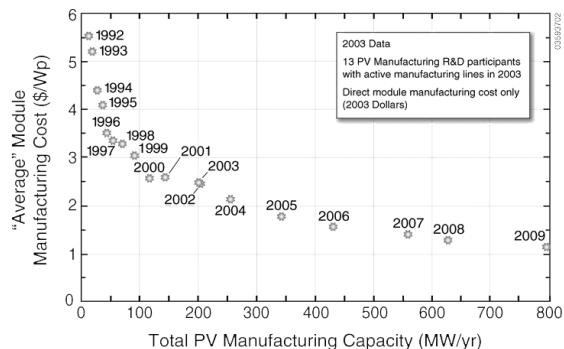


Fig. 1. U.S. PV module manufacturing cost-capacity for combined thin-film and non-thin-film manufacturers

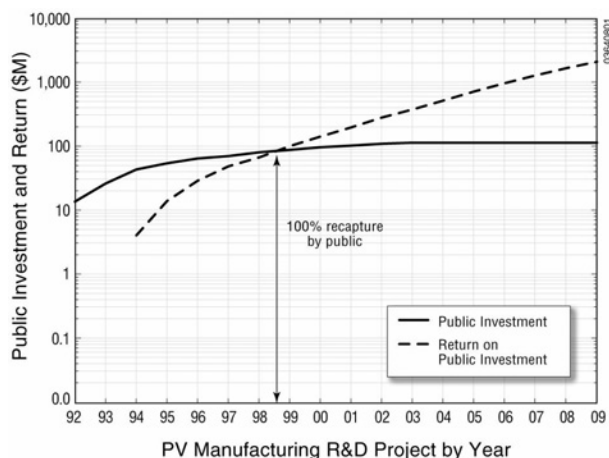


Fig. 2. Recapture of public investment in PVMR&D

\$5.55 to \$2.49 over the same time period, a 6.5% compound annual reduction.

In addition, PVMR&D tracks the manufacturing cost savings resulting from improvements implemented under project subcontracts. Public savings is calculated based on measurable price reductions, while industry savings is equivalent to the amount retained by the manufacturers. For both the private and public sectors, estimated cost savings exceeded investment during 1998, with a discounted-cash-flow rate of return at 40%.

3.2 In-Line Diagnostics & Intelligent Processing

Under IDIP, PVMR&D awarded a total of fourteen subcontracts (Tables 2-3), ten of which are on-going to date. The work performed under these subcontracts represents a broad range of activities throughout the PV industry, from encapsulant development to wafer fabrication to complete system integration.

Table 2. IDIP-Module Manufacturing Subcontractors

Module Manufacturing Category	
Subcontractor	Subcontract Title
AstroPower, Inc.	High Volume Manufacturing of SiliconFilm Solar Cells and Modules
BP Solar	Large-Scale PV Manufacturing Using Ultra-Thin Polycrystalline Silicon Solar Cells
Energy Conversion Devices, Inc.	Implementation of a Comprehensive On-Line Close-Loop Diagnostic System for Roll-to-Roll Amorphous Silicon Solar Cell Production
Energy Photovoltaics, Inc.	Productivity Enhancement for Manufacturing of Amorphous Silicon PV Modules
Evergreen Solar, Inc.	Innovative Approaches to Low Cost Module Manufacturing of String Ribbon Si PV Modules
ITN Energy Systems	Trajectory-Oriented and Fault Tolerant Based Intelligent Process Control for Flexible CIGS PV Module Manufacturing
RWE Schott Solar, Inc.	EFG Technology and Diagnostics R&D for Large-Scale Manufacturing
Shell Solar Industries	PV Manufacturing R&D-Integrated CIS Thin-Film Manufacturing Infrastructure

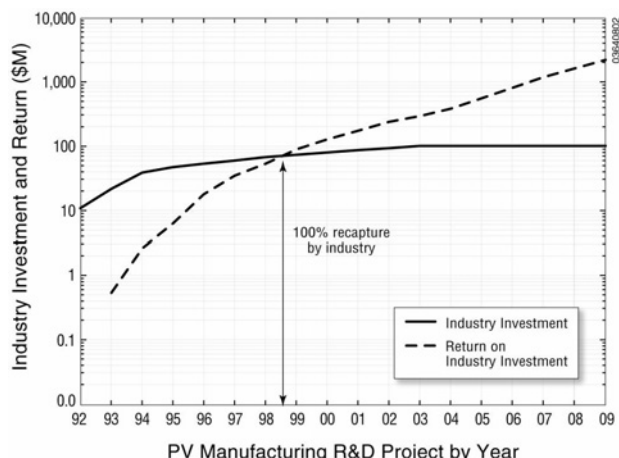


Fig. 3. Recapture of industry investment in PVMR&D

Table 3. IDIP-System Component Subcontractors

PV System & Component Category	
Subcontractor	Subcontract Title
PowerLight Corporation	PowerGuard Lean Manufacturing
RWE Schott Solar, Inc.	Plug and Play Components for Building-Integrated PV Systems
Sinton Consulting, Inc.	Development of an In-Line Minority-Carrier Lifetime Monitoring Tool for Process Control during Fabrication of Crystalline Silicon Solar Cells
Specialized Technology Resources, Inc.	Development of New Low-Cost, High-Performance, PV Module Encapsulant/Packaging Materials
Spire Corporation	Development of Automated Production Line Processes for Solar Brightfield Modules
Xantrex Technologies, Inc.	PV Inverter Products Manufacturing and Design Improvement for Cost Reduction and Performance Enhancements

3.2 Yield, Durability & Reliability

Subcontract negotiations for the YDR procurement are currently underway. Upon review of the 29 Letters of Interest (LOIs) submitted for this solicitation, seventeen of the LOIs were determined to be within the competitive range and considered for funding.

4. Conclusions

Through subcontracted research activities, PVMR&D has promoted significant advances in the PV-related manufacturing sector with respect to cost reductions and capacity scale-up, while improving manufacturing processes and commercial products.

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