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C. Coggeshall
New West Technologies, LLC

R. M. Margolis
National Renewable Energy Laboratory

National Renewable Energy Laboratory
A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Innovation for Our Energy Future

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Technical Report
NREL/TP-6A2-47866
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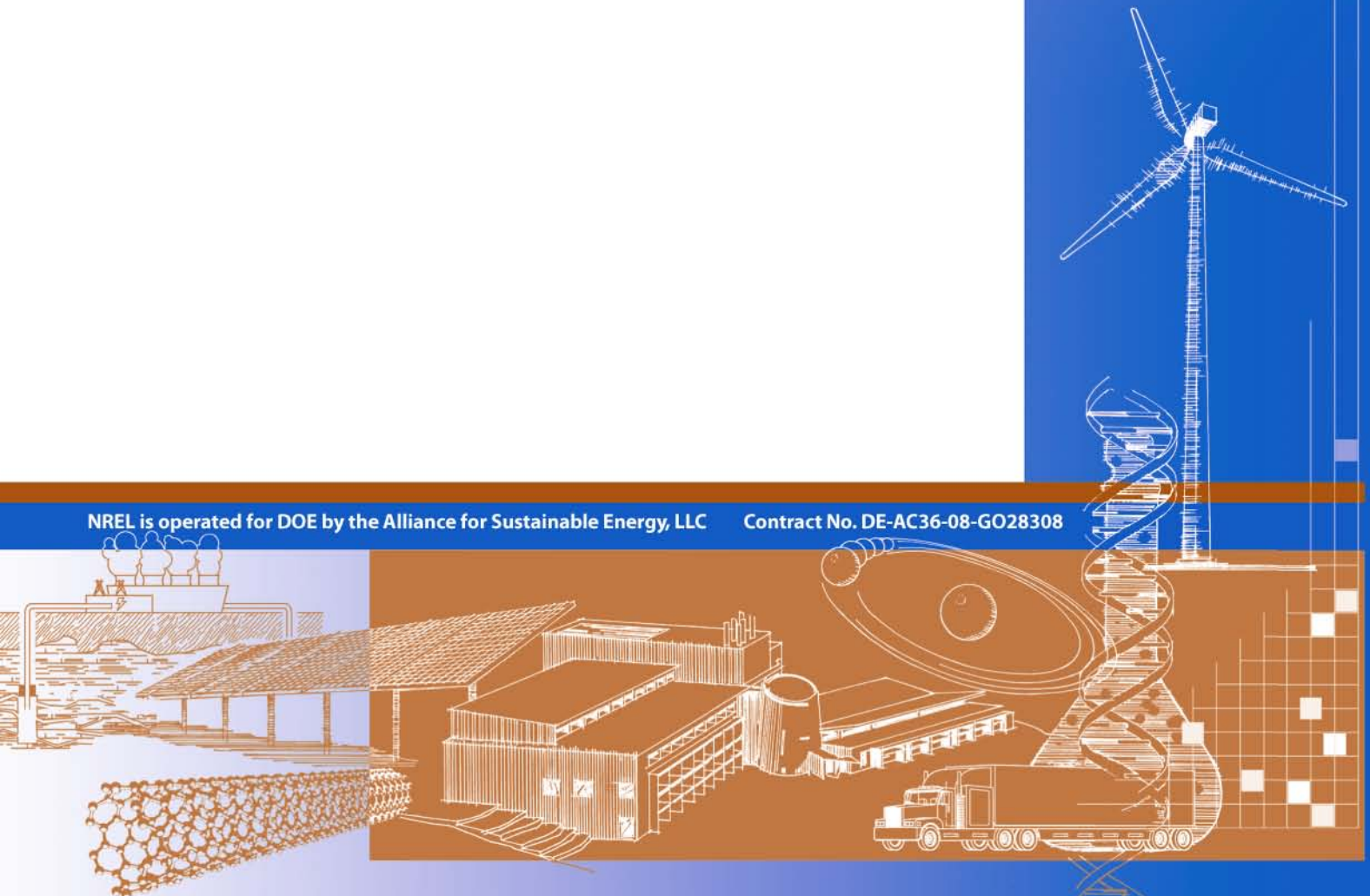

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Charlie Coggeshall
New West Technologies, LLC

Robert M. Margolis
National Renewable Energy Laboratory

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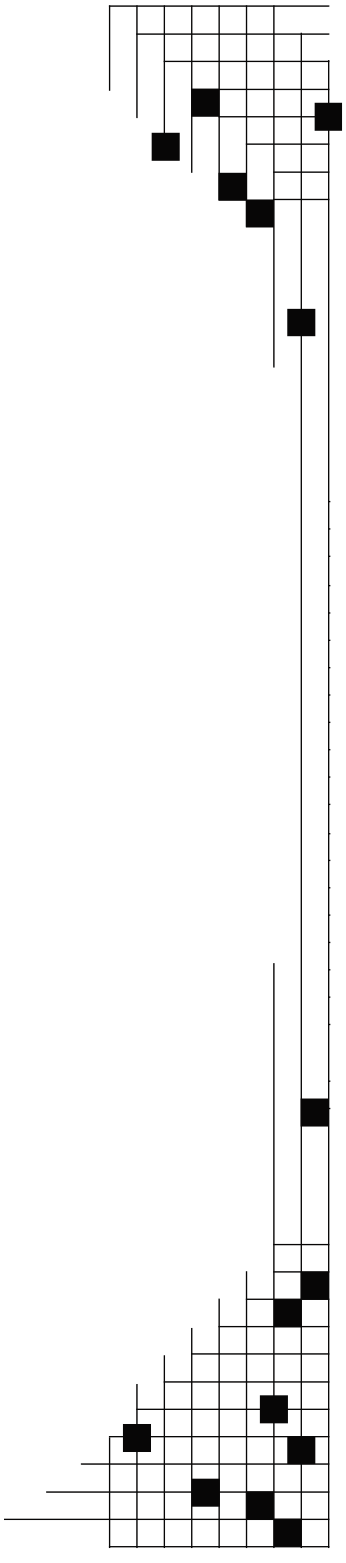

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

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Abstract

As the U.S. Department of Energy's (DOE's) Solar Energy Technologies Program prepares to initiate a new cost-shared research and development (R&D) effort on photovoltaic (PV) manufacturing, it is useful to review the experience to date with consortia focused on PV R&D, manufacturing, and testing. Information was gathered for this report by conducting interviews and accessing Web sites of 14 U.S. consortia and four European consortia, each with either a primary focus on or an emerging interest in PV technology R&D, manufacturing, or testing. Additional input was collected from several workshops held by the DOE and National Academy of Sciences (NAS) in 2009, which examined the practical steps – including public-private partnerships and policy support – necessary to enhance the United States' capacity to competitively manufacture photovoltaics. This report categorizes the 18 consortia into three groups: university-led consortia, industry-led consortia, and manufacturing and testing facilities consortia. The first section summarizes the organizations within the different categories, with a particular focus on the key benefits and challenges for each grouping. The second section provides a more detailed overview of each consortium, including the origins, goals, organization, membership, funding sources, and key contacts. This survey is a useful resource for stakeholders interested in PV manufacturing R&D, but should not imply endorsement of any of these groups.

Acknowledgments

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List of Acronyms

ASU	Arizona State University
BMU	German Federal Ministry for Environment, Nature Conservation and Nuclear Safety
CC	Crystal Clear
CNSE	College of Nanoscale Science and Engineering
CPV	concentrating photovoltaics
CRSP	Center for Revolutionary Solar Photoconversion
CSE	(Fraunhofer) Center for Sustainable Energy Systems
CSM	Colorado School of Mines
CSP	concentrating solar power
CSU	Colorado State University
CU	University of Colorado
DOD	Department of Defense
DOE	Department of Energy
E2TAC	Energy and Environmental Technology Applications Center
EFRC	Energy Frontier Research Center
ECN	Energy research Center of the Netherlands
FCRP	Focus Center Research Program
GRC	Global Research Collaboration
IEC	Institute of Energy Conversion
IMEC	Interuniversity Microelectronics Centre
ITRS	International Technology Roadmap for Semiconductors
I/UCRC	Industry and University Cooperative Research Program
IP	intellectual property
MIT	Massachusetts Institute of Technology
MRI	Midwest Research Institute
NAS	National Academeny of Sciences
NCSU	North Carolina State University
NENY	New Energy New York
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
OSU	Ohio State University
PTL	(TUV Rheinland) Photovoltaic Testing Laboratory
PV	photovoltaics
PVIC	(Wright Center for) Photovoltaics Innovation and Commercialization
RFI	request for information
RFP	request for proposal
SRC	Semiconductor Research Corporation
SiSoC	Silicon Solar Consortium (Research Center)
SolarTAC	Solar Technology Acceleration Center
SVLG	Silicon Valley Leadership Group
TSEC	The Solar Energy Consortium
UT	University of Toledo

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Introduction

As the U.S. Department of Energy's (DOE's) Solar Energy Technologies Program prepares to initiate a new effort aimed at supporting industry and university collaborative activities in photovoltaic (PV) manufacturing research and development (R&D) it is useful to review the experience to date with PV R&D, manufacturing, and testing-focused consortia.[1] Recently, stakeholders have raised concerns about the limited participation of U.S. manufacturers in this rapidly growing industry. The DOE held a series of workshops with the National Academy of Sciences (NAS) during the spring and summer of 2009.[2] These workshops examined the practical steps – including public-private partnerships and policy support – necessary to enhance the United States' capacity to competitively manufacture photovoltaics. In late summer 2009, the DOE released a request for information (RFI) regarding the PV Manufacturing Initiative. The DOE expects to release a request for proposals (RFP) for this initiative in early 2010.

This report provides an overview of 14 U.S. consortia and four European consortia, each with either a primary focus on or an emerging interest in PV technology R&D, manufacturing, or testing. Table 1 provides a list of organizations included in this document. This table provides a good starting point for understanding the range of potential pathways for developing PV-related consortiums. As shown in Table 1, the consortia have been categorized into three groups: university-led consortia, industry-led consortia, and manufacturing and testing facilities consortia.[3] Though categorizing the consortia by grouping was straightforward for most of the organizations, a few span more than one category. In these cases, consortia have been grouped based on their main focus.

Participation within these consortia vary by organization, but may include companies, universities, laboratories and other research groups, utilities, trade associations, and state and local governments. Incentives to join a consortium range from the ability to access additional resources for a competitive advantage to supporting industry-wide growth.

The consortia examined in this report vary considerably with respect to the areas along the PV supply chain in which they focus (i.e., research, development, demonstration, and deployment), and in the resources and capabilities used in achieving their goals. For some, emphasis is on innovative research at the basic and/or fundamental levels (upstream) of PV manufacturing, while others are more concerned with applied research and/or testing and evaluation of new PV technologies. Furthermore, some organizations are forum-based and attempt to facilitate communication among industry players to improve standards and/or open research opportunities, while others are more facility-based and focus primarily on sharing physical resources for carrying out R&D, manufacturing prototyping, and/or testing.

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[1] The terms "consortia" and "consortium" are used interchangeably in this document. Definitions of these terms vary and can be subjective; however, for the purpose of this report, they will be considered to broadly encompass any type of collaboration between two or more organizations.

[2] National Academies, "The Future of Photovoltaic Manufacturing in the United States," April 23, 2009; and, "State and Regional Innovation Initiatives: Partnering for Photovoltaic Manufacturing in the United States," July 29, 2009, National Academy of Sciences, Washington, D.C.

[3] Note that this categorization is slightly different than the groups listed in the DOE RFI: university-led consortia, collaborative industry-led consortia, and manufacturing development facilities.

Most of the organizations included in this report are nonprofit and funded in a variety of different forms. Federal, state, and local governments provide a significant source of funding, as do membership fees, fee-for-service, and contract fees. In addition, many organizations use time and cost-share arrangements.

There are a number of key challenges to carrying out collaborative R&D on PV technologies. First, the PV value/supply chain is very complex; therefore, it can be challenging to meet the needs and interests across different subgroups within the PV technology sector. As a result of this complexity, it may be appropriate to develop specialized consortia focused on narrow crosscutting areas within the supply chain, or on specific PV technologies. Second, concerns over intellectual property (IP) and proprietary information may limit the appetite for private industry to participate in shared activities. The high level of competitiveness in the PV industry, which is still an emerging industry in many ways, has led to a very secretive research environment. Third, industry-university collaboration may pose challenges if faculty and students are unable to publish their research results due to IP constraints. Lastly, it can be challenging to maintain a good balance of funding and benefits to individual participating entities.

The recent growing interest in using consortia to advance PV manufacturing is partly based on the experience and success of using this approach to support the U.S. (and global) semiconductor industry during the past couple of decades. Increased competition from Japanese producers in the 1980s fostered the development of several collaborative initiatives, such as the Semiconductor Research Corporation (SRC) and SEMATECH (both discussed in this report). Similar to the PV manufacturing industry, the semiconductor industry was (and still is) a highly secretive and competitive industry with a limited propensity to share information among competing firms. The cooperation achieved by consortia such as SEMATECH is noteworthy and can offer lessons in forming collaborations based on technology development and manufacturing productivity. A key difference between these industries is that where the semiconductor industry focused primarily on one material (silicon), the PV manufacturing industry has numerous materials with varying technology-specific processes. Consequently, less neutral ground is available to develop standards and share information at the upstream level of the PV value chain.

The body of this report is divided into two sections. The first summarizes the organizations by category, with a particular focus on the key benefits and challenges for each grouping. The second section provides a more detailed overview of each consortium, including information on each consortium's origins, goals, organization, membership, funding sources, and key contacts. Most of the information gathered in this report is from a combination of the presentations given at the NAS workshops,[4] individual consortium Web sites, and discussions with key people in the organizations. This survey is a useful resource for stakeholders interested in PV manufacturing R&D, but should not imply endorsement of any of these groups.

[4] See the References page at the end of this document for details on the NAS workshop presentations.

Table 1. Consortiums Included in this Report

Consortium	Organization	Funding Source	Participants	PV focus?	Years
University-Led Consortia					
Center for Revolutionary Solar Photoconversion (CRSP)	nonprofit	State, Fed, Fee	Uni, Lab, Industry	Primary	2
Energy and Environmental Technologies Applications Center (University of Albany)	nonprofit	State, Fed, Fee	Uni, Industry	Secondary	10
Institute of Energy Conversion (University of Delaware)	nonprofit	Fed, Fee	Uni, Industry	Primary	30+
Semiconductor Research Corporation (SRC)	nonprofit	Fed, Fee	Uni, Lab, Industry	Emerging	/
Silicon Solar Consortium (SiSoC) Research Center	nonprofit	Fed, Fee	Uni, Lab, Industry	Primary	2
SolarFocus	nonprofit	Fed, Fee	Uni, Lab, Industry	Primary	3
Wright Center for Photovoltaics Innovation and Commercialization (PVIC)	nonprofit	State, Fed, Fee	Uni, Lab, Industry	Primary	3
Industry-Led Consortia					
CPV Consortium	nonprofit	Fee	Industry	Primary	2
Crystal Clear	nonprofit	Fed, Fee	Uni, Lab, Industry	Primary	5
Fraunhofer-CSE	nonprofit	State, Fee	Uni, Industry	Primary	1
IMEC	nonprofit	Fee	Uni, Lab, Industry	Secondary	20+
SEMATECH	nonprofit	Fee, Reg. govt	Uni, Lab, Industry	Emerging	/
SEMI PV Group	nonprofit	Fee, Events	Industry	Secondary	2
SolarTech	nonprofit	State, Fee	Industry	Primary	4
The Solar Energy Consortium	nonprofit	State, Fed, Fee	Uni, Industry	Primary	3
Manufacturing and Testing Facilities Consortia					
SolarTAC	nonprofit	Fee	Uni, Lab, Industry, Utilities	Primary	1
SVTC Solar	for-profit	Fee	Uni, Lab, Industry	Primary	2
TUV Rheinland PTL	for-profit	Fee	Uni, Industry	Primary	2

University-Led Consortia

The university-led consortia includes a range of organizational dynamics and structures, but the greatest common denominator is that the R&D activities are largely conducted within a university facility and carried out primarily by university faculty, staff, and students. In addition, the universities often restrict access to these physical resources and human capital to affiliated industrial partners. However, there is no standard model, and these elements, as well as others, can vary by consortium. Below is a list of the university-led consortia discussed in this report.

- Center for Revolutionary Solar Photoconversion (CRSP)
- Energy and Environmental Technology Applications Center (E2TAC) at the College of Nanoscale Science and Engineering (CNSE)
- Institute of Energy Conversion (IEC) (University of Delaware)
- Semiconductor Research Corporation (SRC)
- Silicon Solar Consortium (SiSoC) Research Center
- SolarFocus
- Wright Center for Photovoltaics Innovation and Commercialization (PVIC)

The organizations listed above are nonprofit and rely, at least in part, on federal funding. Specific programs such as the DOE's office of Basic Energy Sciences Energy Frontier Research Centers (EFRCs), the DOE's Solar Energy Technologies Program (Solar Program), and the National Science Foundation's Industry and University Cooperative Research Program (I/UCRC) have contributed to research at CRSP, IEC, and SiSoC, respectively. The groups have also secured public funding through state grants and matching programs for organizations such as CRSP, E2TAC, and PVIC. All of the organizations listed in this grouping receive some level of funding through fee-for-service projects and/or negotiated contracts. In addition, CRSP, SiSoC, and PVIC offer membership for their organizations that entails a corresponding fee. Membership fees account for 80% of the total funding for SiSoC; are one of the primary sources of funding for CRSP, SRC, and SolarFocus; and are a secondary source for PVIC.

Another differing variable in the listed organizations is that CRSP, SiSoC, and PVIC all include multiple universities within their respective consortia. For example, CRSP is codirected by faculty and staff from the University of Colorado at Boulder (CU), Colorado School of Mines (CSM), Colorado State University (CSU), and the National Renewable Energy Laboratory (NREL). Similarly, PVIC is codirected by faculty and staff from the University of Toledo (UT) and Ohio State University (OSU). It should be noted that UT is the official "administrative lead" for the collaborative, and that Bowling Green State University is also a partner within the PVIC group. SiSoC's primary director and site location are at North Carolina State University; while Georgia Tech University has a codirector role in the consortium, and there are multiple other universities that are active members. The level of collaboration and resource sharing among the universities within each consortium can vary depending on the research project and/or negotiated contract. It should be noted that some of these organizations blur the line between the university-led consortia and industry-led consortia due to overlap in leadership and facilities.

University-led consortia offer unique benefits to the PV manufacturing industry, which include developing an educated PV workforce, conducting innovative research, and supporting interactive collaborations. One of the strongest potential benefits of engaging universities in PV

manufacturing R&D is that they produce graduates with PV experience. All of the organizations listed as university-led consortia in this document use graduate and postdoctoral students for research conducted through their respective consortium programs. It is widely believed that the U.S. PV industry would benefit from an increase in "homegrown" professionals. Another benefit of university-led consortia is that university professors, staff, and students are typically involved in cutting-edge research and, thus, can offer industrial partners insights that challenge conventional wisdom and ultimately foster innovation. Finally, resource constraints and a willingness to share information foster an environment and culture that are conducive to collaboration. Universities are often experienced in and open to forging relationships to achieve greater research goals.

Although there are potential benefits of university-led consortia, there are also key challenges, most of which evolve from potential conflicts of interest and concerns about ownership of intellectual property between university and industry partners. Universities tend to invest their resources into thesis-oriented fundamental and/or basic research issues, with the primary objective of achieving peer-reviewed publications. Conversely, industry is most concerned with conducting applied and/or commercialization research to produce confidential results in a short time. These different objectives pose a challenge for universities that may lack the equipment and expertise to meet industry's research demands and/or may be restricted from publishing their research results. In addition, issues can occur where a company's interests are not compatible with the requirements of a student's thesis including the distribution of IP therein and/or the time necessary for developing thesis-level research. As a consequence, industry may be hesitant to enter collaborations with universities that are less experienced with applied research and are unfamiliar with the significance of protecting IP from competing interest.

Industry-Led Consortia

Similar to university-led consortia, industry-led consortia vary significantly in their organizational designs and objectives. Most of the organizations in this group are membership-based. They cover a diverse set of topics and activities from carrying out applied R&D to working on standard setting and commercialization. Below is a list of industry-led consortia that are identified in this document.

- CPV Consortium
- Crystal Clear (CC)
- Fraunhofer-CSE
- Interuniversity Microelectronics Centre (IMEC)
- SEMATECH
- SEMI PV Group
- SolarTech
- The Solar Energy Consortium (TSEC)

All of the organizations listed above are nonprofit and, with a few exceptions, most rely on membership fees as a primary source of funding. SolarTech, SEMATECH, and IMEC have all secured some level of regional government funding in addition to membership fees. The SEMI PV Group receives additional funding through expositions.

Some of these organizations have existed for a number of years but only recently added PV efforts to their portfolio. For such organizations, including SEMATECH and SEMI, photovoltaics are still a relatively small part of their overall effort. Other organizations, such as Crystal Clear and TSEC, were specifically founded to focus on collaborative PV activities. Similar to SRC and SolarFocus (discussed in the University-Led Consortia section), Fraunhofer-CSE is a mix between university-led and industry-led consortia in that there is collaboration with a university (Massachusetts Institute of Technology) involving facility and research capabilities.

Industry-led consortia can provide important benefits to the PV industry, including offering an open forum for firms to interact and identify best practices, and creating and/or promoting collaborative research and development projects based on shared costs and benefits. Developing a credible consensus on industry standards and road mapping could also benefit the PV industry. While some industry-led consortia provide forums for PV market players to communicate, others provide specialized facilities for carrying out R&D collaboration. A consortium can provide pre-established guidelines for how these arrangements are made, thereby shortening time invested in lengthy negotiations and reducing uncertainty over important issues, such as costs and confidentiality. A consortium can also provide a vehicle for connecting organizations that have mutually beneficial research needs and/or interests.

Industry-led consortia face several related challenges in accomplishing their goals, including managing a diverse set of companies and their respective interests, and addressing the issue of confidentiality (i.e., intellectual property and proprietary information). Establishing a consortium in the PV manufacturing industry also presents challenges in understanding the diversity and depth of the PV value chain. There are dozens of technology groups and subgroups within the PV industry, which have many different attributes. This diversity makes the development of any industry-wide consensus, such as manufacturing standards, extremely difficult.

Furthermore, the complexity and diversity of the technology groups in the market has resulted in a wealth of perceived opportunities and, therefore, competitiveness among industry players: With so many different PV technologies being developed and evolving rapidly, there is reason for PV companies to be protective of their IP. As a result, companies are less likely to participate in forums that could expose their proprietary information. They are also less likely to partake in collaborative research that presents a threat to their IP or could expose their trade secrets.

Manufacturing and Testing Facilities Consortia

Manufacturing and testing facilities consortia offer new or retooled facilities that assist PV companies in making the transition to commercial production. They provide services ranging from testing and certification to production and process support. A distinction between this group and the consortia previously mentioned in this document is that intellectual property is generally not shared beyond the user company, although there are exceptions (described in this section). Below is a list of PV manufacturing and testing facilities consortia discussed in this report:

- Solar Technology Acceleration Center (SolarTAC)
- SVTC Solar
- TUV Rheinland Photovoltaic Testing Laboratory (TUV Rheinland PTL)

TUV Rheinland PTL and SVTC Solar are for-profit organizations primarily funded through fee-for-service mechanisms. SolarTAC, a nonprofit, is funded primarily through membership fees. SolarTAC has a particularly flexible structure – it offers companies the ability to participate in proprietary, collaborative, and/or publicly shared activities. In contrast, TUV Rheinland PTL and SVTC Solar generally require that the IP developed through their respective facilities is owned only by the user companies. TUV Rheinland PTL is different from SVTC Solar in that it uses the facilities and students at a public institution via a joint venture between TUV Rheinland and Arizona State University (ASU). In fact, more than half of the TUV Rheinland PTL staff members are ASU students, and an ASU faculty member is the president of TUV Rheinland PTL. All three of these consortia have the tools and resources to conduct testing of PV technology and equipment; however, SVTC Solar can also directly support the R&D involved in the manufacturing processes for each segment of the PV supply chain (e.g., equipment makers, material suppliers, panel makers, etc).

Organizations that share manufacturing and testing facilities could offer the PV industry several benefits, which include reducing development costs and times, and mitigating technology risks for potential investors. Shared PV manufacturing and testing facilities and the expertise offered with them can provide companies with a cost- and time-effective means for testing and developing the commercialization and scalability of their PV products. Companies can avoid the significant capital investment in equipment and expertise that would normally be required to prove manufacturability and product reliability. These facilities also provide a bridge over what has been referred to as the "Solar Valley of Death," the development and commercialization phase where emerging companies lack the resources to prove their manufacturing capability to potential investors. These types of manufacturing and testing facilities have the potential to provide an affordable resource for testing and/or developing new manufacturing processes and/or product reliability for PV technology and related equipment.

As with the other consortia models discussed in this report, confidentiality remains a key issue for PV manufacturing and testing facilities consortia. Sensitivity to IP and proprietary materials/processes can restrict a company's willingness to share its information with an organization that works with other companies on related manufacturing issues. Another challenge is finding a source of funding to support the creation and/or maintenance of the manufacturing facility. Establishing a facility and outfit with the expertise necessary to support service contracts and maintenance of equipment requires substantial capital.

Center for Revolutionary Solar Photoconversion (CRSP)

Background

Founded in March 2008, the Center for Revolutionary Solar Photoconversion (CRSP) is one of six research centers initiated by the Colorado Renewable Energy Collaboratory.[5] Specifically, CRSP provides basic and applied research for third-generation solar photon conversion. CRSP members can use the four institutions' resources and capabilities through three programs, including:

- Shared research: CRSP members help select pre-competitive shared research projects and receive royalty-free, worldwide, nonexclusive licenses to the resulting technologies. Shared research projects are supported by a pool of funds created from membership fees, funding from the Colorado Renewable Energy Authority, and potentially other sources.
- Sponsored research: Any member may contract with one or more of the CRSP institutions (via a single agreement with CRSP) for an independently funded, sponsored research project that focuses on specific areas of interest, including results of shared research projects. In addition, exclusive licensing is available.
- Federally awarded: The CRSP institutions receive funding from the U.S. DOE and other agencies to conduct basic research on novel approaches to solar photon conversion.

Goals

The goal of CRSP is to engage in research resulting in technologies, over the long-term, that can produce electricity and liquid and gaseous fuels at costs competitive with energy produced from coal. In 2009, research on photoconversion into electricity included a focus on inorganic materials and novel device architectures for advanced solar cells, novel organic/polymeric/hybrid inorganic-organic solar cells, and third generation PV. Research on photoconversion into fuels included new materials and approaches for efficient solar water splitting, and photoreduction of CO2 with water to fuel.

Organization

The CRSP Executive Board includes a scientific director (Dr. Arthur J. Nozik, senior research fellow at NREL), three codirectors (Dr. David Jonas at CU, Dr. Mike Elliott at CSU, and Dr. Craig Taylor at CSM), and a managing director (Paul Nelson, affiliated with NREL and CU). In addition, the CRSP Advisory Panel includes one representative from each of the member companies. CRSP member companies play a key role in identifying shared research areas and selecting projects for funding. In turn, the CRSP Scientific Advisory Board (led by Dr. Thomas J. Meyer of University of North Carolina at Chapel Hill and external experts) evaluates and monitors the quality of the science performed by CRSP researchers.

[5] The Solar Technology Acceleration Center (SolarTAC) is another center initiated by the Colorado Collaboratory and is summarized in this report. The Collaboratory is a research partnership that includes the National Renewable Energy Laboratory, Colorado State University, the University of Colorado at Boulder, and the Colorado School of Mines. Each center works with industry partners, public agencies, and other universities and colleges, while pursuing shared, sponsored, and federally funded research to: (1) address the scientific challenges for key renewable energy technologies; (2) create and speed the commercialization of renewable energy technologies, energy management systems, and energy efficiency; (3) support economic growth in Colorado and the nation for renewable energy industries; and (4) educate our nation's finest energy researchers, technicians, and workforce.

CRSP Membership

Founding Corporate Members		General Members
Applied Materials Inc.	Motech Industries Inc.	Toyota
Ascent Solar Technologies Inc.	QuantumSphere Inc.	General Motors
DuPont	Sharp Corporation	Tokyo Electron
Evident Technologies Inc.	Solasta Inc.	ZettaSun
Konarka Technologies Inc.	SunEdison LLC	G24 Innovations
Lockheed Martin		

Source: CRSP Web site, accessed November 22, 2009.

Funding

Since its inception in 2008, CRSP has been funded by a combination of membership fees, state and federal funding, and a few case-by-case sponsored research contracts. Annual membership fees, which require a minimum two-year commitment, vary by the size of the company, ranging from $10,000 for fewer than 500 employees, to $50,000 for more than 500 employees. CRSP's annual membership revenue in 2009 was more than $500,000. As a Colorado Renewable Energy Collaboratory Center, CRSP's membership revenue is matched 1:1 by the State of Colorado. Therefore, CRSP had approximately $1 million in funding during 2009 to support shared research seed grants.

In April 2009, CRSP was selected to participate in a new DOE Energy Frontier Research Center (EFRC) named the Center for Advanced Solar Photophysics. CRSP research institutions will receive $1.3 million annually from a total of about $3.8 million a year awarded to Los Alamos National Laboratory over a five-year period. NREL, CU, and CSM will be the CRSP research institutions involved in the EFRC with NREL conducting the majority of the research. The Collaboratory is also providing $100,000 annually for three years as a match to the federal EFRC dollars that go to the participating CRSP universities. In fall 2009, CRSP partnered with the new National Science Foundation (NSF) Renewable Energy Materials Research Science and Engineering Center, at the Colorado School of Mines. The partnership includes significant NREL involvement and some participation from CU.

Sponsored research began in late 2009 and is expected to increase as the CRSP shared-research projects are concluded and membership grows. Out-of-state universities that partner with CRSP must co-fund the research so that State of Colorado funds are not sent out-of-state.

Contact

Paul A. Nelson
Managing Director, CRSP
paul.nelson@colorado.edu
303-492-8025

www.coloradocollaboratory.org/crsp/

Energy and Environmental Technology Applications Center (E2TAC) at the College of Nanoscale Science and Engineering (CNSE)

Background

The Energy and Environmental Technology Applications Center (E2TAC) is part of the College of Nanoscale Science and Engineering (CNSE) at the University of Albany, New York. E2TAC addresses advanced energy and environmental applications by leveraging a $5 billion, 800,000-square-foot megaplex and the intellectual resources at CNSE. E2TAC was established as an expansion of CNSE's nanotechnology research to work with companies in the emerging energy and environmental industries. Most of E2TAC's actual facility work focuses on process, equipment, and device development at the manufacturing scale. E2TAC has worked on all aspects of silicon and non-silicon solar cell technologies for the past 10 years.

Goals

E2TAC's mission is to "support energy and environmental technology deployment through accelerated commercialization by incorporating nanotechnology innovations and leveraging partnerships between industry, government, and university."[6]

Organization

E2TAC partners with more than 50 corporations. Corporate partners have access to the state-of-the-art laboratories, clean rooms, metrology equipment, and various scientific centers and resources within the CNSE.

E2TAC does not have a membership system. Instead, they build long-term relationships with industries that co- or virtually locate at CNSE and provide consistent and ongoing contracts. Some of the CNSE partners have included IBM, Applied Materials, SEMATECH, Global Foundaries, Tokyo Electron, and Atotech. E2TAC is a founding member of the NREL Clean Energy Alliance and the New Energy New York (NENY) consortium.

Funding

The state provided part of the seed funding (~$1 billion) for the $5 billion CNSE complex, and the rest came from industry. The E2TAC solar effort has been funded at a level of several million dollars annually during the past couple of years, and is anticipated to experience significant growth during the next few years based on new partnerships being established. Most of the funding for the solar program comes from industry contracts, with some coming from New York State, and the remainder from federal sources.

Contact

Pradeep Haldar, Director
phaldar@uamail.albany.edu
518-437-8684

www.e2tac.org/

[6] E2TAC Web site, accessed at http://www.e2tac.org/about.html

Institute of Energy Conversion (IEC), University of Delaware

Background

The Institute of Energy Conversion (IEC) was established at the University of Delaware in 1972. It is an integrated laboratory devoted to R&D of thin-film PV solar cells. Areas of focus include copper indium diselenide and related alloys; cadmium telluride; and amorphous, nanocrystalline, and crystalline silicon solar cells. IEC maintains complete facilities for fabrication and characterization of state-of-the-art solar cells in all of these technologies. In 1992, the DOE designated IEC as a Center of Excellence for Photovoltaic Research and Education. IEC leveraged this funding and the expertise it developed under government support by expanding collaboration with industry, universities, other government agencies, and national laboratories.

Goals

IEC's mission is to develop the fundamental science and engineering base required to improve PV device performance and processing technologies, as well as effectively transfer these laboratory results to large-scale manufacturing.

Organization

The institute is staffed by approximately 20 professional and support personnel, along with approximately 20 faculty, visiting scholars, postdoctoral fellows, and graduate and undergraduate students. There is close collaboration between IEC staff and thin-film PV industrial partners. IEC does not maintain an official partnership or membership base.

Funding

IEC has been and continues to be funded primarily through DOE-sponsored research programs as well as industrial contracts. DOE renewed funding several times through IEC's designation as a Center of Excellence for Photovoltaic Research and Education. Although IEC is no longer supported through this program, it receives funding from the DOE through the Solar Program's Next Generation and Supply Chain programs. IEC is also supported through collaborative contracts with industry. This past year, IEC held nearly 40 collaborative agreements with both domestic and international companies. Contracts can be fee-for-service (which are generally short term), or long-term research-oriented contracts. During the past two years, IEC's collaboration with industry has expanded. IEC has licensed patents to multiple companies and also supports development of their commercial-scale process. It is important to note that IEC is a totally self-supported ("soft funded") unit of the University of Delaware.

Contact

Robert Birkmire, Director
rwb@udel.edu
302-831-6220

www.udel.edu/iec/

Semiconductor Research Corporation (SRC)

Background

The Semiconductor Research Corporation (SRC) was created in 1982 to support the semiconductor industry with contributions from university research. Today, SRC includes a network of more than 250 universities around the world, and nearly 20 member companies at any given time. SRC uses collaborative research to focus on precompetitive design, materials, and process technology in the semiconductor industry. SRC's "community" includes more than 1,700 faculty members and 7,400 students, and it is responsible for publishing 20% of the world's research on silicon.

SRC is not invested in solar-specific research. However, the consortium is actively seeking opportunities to apply its experience and capabilities within the PV manufacturing industry, and it plans to announce the formation of a new energy research consortium in early 2010.

Goals

"The SRC's Mission is to manage a range of consortial, university research programs some of which are worldwide, each matching the needs of their sponsoring entities. SRC maximizes synergy between programs to optimally address members' research needs and minimizes redundancy to maximize value to common members."[7]

Organization

SRC has three primary subsidiaries: the Global Research Collaboration (GRC), which drives near-term materials, interconnect, devices, design, and tools progress; the Focus Center Research Program (FCRP), which supports future generations of integrated circuit requirements; and the Nanoelectronics Research Initiative, which is responsible for determining the post-CMOS information element by 2020. In addition, SRC manages Topical Research Collaborations in specific areas of interest to industry and government such as nanoengineering and energy.

As stated above, SRC is creating a PV-focused consortium. The organization and operating procedures will be decided by a Governing Council, consisting of one representative from each sponsor, until a more formal operational model is identified. For existing programs, the FCRP gives the center directors/theme leaders the autonomy to choose projects and research directions; whereas the GRC allows sponsors to take an active role in determining strategic directions and choosing projects through executive and technical advisory boards. Leveraging their participation, the member companies direct and receive early access to the research results. Members also cultivate early interaction with the thousands of students who collaborate in the work.

[7] SRC Web site, accessed at http://www.src.org/member/about/mission.asp

Funding

SRC is primarily funded through membership fees from industry, with some funds awarded through government grants and contracts. Each of the three programs seeks separate funding opportunities based on project needs and requests made by industry members.

Contact

Steven Hillenius
Executive Vice President, SRC; and Executive Director, SRC-Global Research Collaboration
Hillenius@src.org
919-941-9418

www.src.org/

Silicon Solar Consortium (SiSoC) Research Center

Background

The Silicon Solar Consortium (SiSoC) Research Center focuses on R&D research areas essential to reaching competitive levels in cost and performance of silicon PV material, PV cells, and PV modules, while developing innovative designs and processes. SiSoC also has an education program for graduate and post-graduate students, which is designed to contribute to and expand on the population of scientists and engineers who have the skills and knowledge necessary to become productive in the PV industry with minimum on-site company training. The Georgia Institute of Technology and North Carolina State University (NCSU), which is the lead institution, maintain research sites to collaborate on research, fabrication, and characterization of advanced PV materials and devices.

SiSoC is an NSF Industry/University Cooperative Research Center (I/UCRC). I/UCRCs are funded by NSF to stimulate highly leveraged industry/university cooperation by focusing on fundamental research recommended by industrial advisory boards.

Goals

"The mission of the Center is to create a multi-university, multi-company culture addressing those science and technology issues the international photovoltaic silicon materials industry must solve in order to meet the future needs of advanced silicon solar cell manufacturing, while educating graduate students with photovoltaic materials/devices expertise."[8]

The center's proposed goal is to help reestablish a global leadership role for the U.S. silicon PV industry by having government – together with the solar-electric power industry – stimulate high quality university-level research and education, while developing an expanded and skilled workforce.

Organization

SiSoC includes two university sites, North Carolina State University (primary site) and Georgia Institute of Technology, with participation from Texas Tech University and Lehigh University. During 2009, about 50% of the research was conducted at NCSU, 30% at Georgia Tech, 10% at Lehigh, and 10% at Texas Tech. Several additional universities have recently been authorized to submit proposals, and SiSoC plans to continue to expand its research base. In addition to universities, SiSoC works with national laboratories and corporations. A full membership list is provided below.

Research projects are confirmed through a collaborative effort between the SiSoC industry and government members and the university principal investigators (PIs). Industry and government SiSoC members create a list of research topics of interest, which the university PIs use as a guideline for proposing research projects. After the proposed projects are established, the members rank the projects through a vote. The group funds the projects with the most votes and that can be accommodated with the budget available. Each running project is assigned a "mentor" from industry who will guide the direction and ensure proper support for the researchers.

[8] SiSoC Web site, accessed at http://www.mse.ncsu.edu/sisoc/

SiSoC Membership List

Industrial Members		University Members
Applied Materials	NREL	Georgia Institute of Technology
Centrotherm (Germany)	REC (Norway)	Lehigh University
Crystal Solar	Sandia National Labs	North Carolina State University
Dow Corning	Semi-Materials (Korea)	Rochester Institute of Technology
DuPont	Sierra Solar	Texas Tech University
Evergreen Solar	Solar Power Industries	University of Washington
GT Solar	SolarWorld	
Heraeus	Sinova	
MEMC	SunPower	
Motech Industries (Taiwan)		

Source: SiSoC Web site, accessed on November 19, 2009

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Funding

Approximately 80% of the funding of SiSoC has been secured through annual membership fees ($10,000 for observer members, $25,000 for associate members, $50,000 for full members). The balance of funding has come from the annual support of the NSF- I/UCRC program. The total funding received between SiSoC's establishment in fourth quarter 2007 and fourth quarter 2009 was approximately $1.36 million – North Carolina State University received approximately $960,000 and Georgia Tech $400,000.

Contact

François Hautin
Operations Director
fdhautin@ncsu.edu
919-513-3927

Prof. George Rozgonyi
Director
rozgonyi@ncsu.edu
919-5-2934

www.sisoc.biz

SolarFocus

Background

SolarFocus is a German-based joint venture project led by 12 PV industry partners and 12 universities/research institutions. Established in 2007, SolarFocus was initially funded over a three-year period by the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU). German PV-silicon materials research clusters started in 1991. This particular project aims to address some of the pre-competitive principal mechanisms of silicon processing, with an emphasis on defect analysis, correlation experiments, and defect engineering. This effort focuses on producing results that will improve the fabrication of silicon wafers and optimize solar cell production.

Goals

The underlying goal of the SolarFocus project is to support and maintain Germany's international leadership in solar cell production and plant engineering. By gaining a better comprehension of the silicon material used in solar cell manufacturing, the SolarFocus project hopes to increase efficiency in solar cells, which will result in cost reductions across the solar industry's value chain.

Organization

The SolarFocus project joins 12 enterprises from the German PV industry with 12 universities and research institutes. Foreign companies are allowed to participate, as long as they have domestic (German) production. The companies represent producers of PV systems based on silicon wafer technology. The research partners have access to a broad range of methods and approaches in studying different aspects of material properties and cell processes.

Although the project was initially funded for a three-year period, there were mechanisms included in the project's organizational structure for adjusting the focus of individual activities over time. In general, industrial partners (universities and institutes) define what work is to be done, and research partners decide who among them should do the work. The consortium projects are managed by a coordination team, which includes a senior project coordinator (from industry), an advisory board that includes two individuals from industry (elected by industry partners) and two individuals from academic/research institutes, and one full-time postdoctoral researcher with an assistant. The industry partners elect and pay the senior project coordinator.

Funding

SolarFocus received € 4.1 million ($5.6 million) in base-funding support from the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety. The government funds are fully committed and distributed to specific groups from the start of the program. The consortium is supported by Projekttraeger Juelich (PtJ), a project management company.

Each industrial partner is required to contribute € 30,000 ($41K) a year for membership, regardless of size. About 10% of the membership contributions support the coordination team, which responds to developments and needs; with the remaining 90% distributed to the research groups in proportion to their own budget. Industry partners also provide in-kind contributions of material, equipment, employee personnel, and research work where it is relevant. When

including nonmonetary contributions, there is about a 50/50 cost-share between government and industry.

Contact

Dr. Wolfgang Koch
Koch Solar Consultancy (KoSolCo GmbH)
Senior Project Coordinator - SolarFocus
w.koch@kosolco.de
+49 9851 555 3835

www.solarfocus.org/index.php?id=1&L=1

Wright Center for Photovoltaics Innovation and Commercialization (PVIC)

Background

Created in January 2007, the Wright Center for Photovoltaics Innovation and Commercialization (PVIC) is a science and technology consortium that focuses on the development of second- and third-generation PV materials. Based in Ohio, the group consists of the University of Toledo ("administrative lead"), Ohio State University, and Bowling Green State University. PVIC also works with agencies and companies to provide fully integrated collaborative R&D, ranging from basic to applied research.

Goals

The primary goals of the PVIC group are to accelerate solar technology into the marketplace, develop and expand the solar industry in Ohio, and create sustainable jobs.

Organization

PVIC is organized around three Ohio campuses: University of Toledo (UT), Ohio State University (OSU), and Bowling Green State University. UT and OSU offer the bulk of resources and capabilities, and balance one another with varying technology expertise. Companies within the PVIC program may use one, two, or all three universities depending on the agreement. Interaction with industry occurs through several different forms, including a fee for use of capital equipment at the universities, collaborations to seek R&D funding from federal and state agencies, direct funding by industry (with shared results), and PVIC membership.

Funding

As part of Ohio's Frontier Program, PVIC initially received $18.6 million from the Ohio Department of Development. Approximate allocations to each university were $9 million to Toledo, $7 million to OSU, and $2 million to Bowling Green.[9] This has represented the bulk of support for the PVIC program through 2009. The PVIC Web site states that it has received "matching" contributions of $30 million from federal agencies, universities, and industrial partners. Most of this funding is represented through various cost-share arrangements. Membership to the program has not been a significant revenue source to date; the membership fee is $5,000 for Ohio companies and $15,000 for non-Ohio companies. OSU receives additional income through fee-for-service activities, and Toledo is planning to offer fee-for-service activities.

Contacts

Robert J. Davis, Ph.D. (OSU Node)
Codirector
davis.2316@osu.edu
614.292.7309

http://pvic.org/

[9] Communication with Bob Davis.

CPV Consortium

Background

Founded in September 2008, the CPV Consortium is a global industry organization focused on making concentrating photovoltaics (CPV) a low-cost source of reliable renewable energy. The CPV consortium is working on three initiatives: (1) assessment of the environmental impact of CPV vs. other solar technologies, (2) evaluating and communicating the cost-competitiveness of CPV technology in large-scale high-sun markets, and (3) working with standard-setting bodies to establish appropriate measurement metrics for CPV, including panel-rating standards.

Goals

The CPV Consortium helps the CPV industry by providing the necessary infrastructure and market understanding that will support CPV technology in meeting the needs of the global energy market. In addition to general marketing and membership building, the CPV Consortium provides education on CPV technology and helps set appropriate performance metrics for the technology as it deploys globally.

Organization

This global nonprofit organization includes members from all segments of the CPV industry, including cell, module, and tracker suppliers; as well as universities and governmental organizations. The founding members include Concentrix Solar (Germany), Emcore (United States), ISFOC (Spain), Isofoton (Spain), and SolFocus (United States). The CPV Consortium is interested in establishing partnerships with universities and research groups who have expertise in solar technology.

Membership in the CPV Consortium is available at several levels: charter membership ($15,000) (includes a seat on the steering committee); general membership ($5,000 for small companies (< $20 million), $10,000 for large companies (> $20 million); informational membership ($1,000 for non-voting member, individual, or consultant); and governmental, university, and non-profit memberships (complimentary, but on an invitation-only basis).

Funding

The CPV Consortium has been funded through 2009 solely through membership fees. The consortium has also been pursuing grant funding for specific programs.

Contact

Claire van Zuiden
Manager
cvanzuiden@cpvconsortium.org
650-623-7160

www.cpvconsortium.org/

Crystal Clear (CC)

Background

Crystal Clear (CC) was an "integrated project," carried out in the 6th Framework Program of the European Union. The project, which ran from January 2004 to June 2009, focused on conducting EU-based crystalline silicon PV technology R&D in a collaborative fashion. Sixteen consortium partners were included in the CC R&D efforts. The initiative covered a range of R&D activities including work on feedstocks, wafers and thin-film wafer-equivalents, cells, modules, cost calculations, and sustainability analyses.

Goals

CC's mission was to reduce the manufacturing costs of wafer-based silicon PV modules to 1 € (~$1.36) per watt-peak or below by reducing materials consumption, increasing cell and module efficiency, and improving productivity. Moreover, CC aimed to improve the environmental quality (in particular, the energy payback time) of PV modules. The project was completed in June 2009, with the demonstration of (among other achievements) a world record-efficient multicrystalline silicon PV module. The technology employs ultra-thin wafers and a novel method for cell interconnection and module assembly, which is based on a pick-and-place process and conductive adhesives.

Organization

The CC project was organized into eight subprojects: five addressed the production chain, one addressed sustainability, one addressed integration aspects, and the final one was dedicated to project management. The project was managed by an Executive Board (representing the General Assembly of all participants) chaired by the project coordinator and supported by the Project Management Office. Although the budget was set for each partner at the beginning of the project, the rolling 18-month work plans were reviewed and renewed every 12 months. This helped with monitoring progress of individual projects and moving projects in new directions where appropriate.

Funding

The project was funded through the 6th Framework Program of the European Union with a budget of € 28 million ($38 million). Of that, nearly € 16 million ($22 million) was contributed by the EU and € 12 million ($16 million) came from the project's 16 partners. While universities were 100% funded, all other partners (research institutes as well as industry partners) had to provide cost-sharing to the projects in which they participated.

Contact

Wim Sinke
Energy research Centre of the Netherlands (ECN)
sinke@ecn.nl
+31 (0) 224 56 40 58

www.ipcrystalclear.info/

Fraunhofer Center for Sustainable Energy Systems (CSE)

Background

In April 2008, Fraunhofer USA partnered with the Massachusetts Institute of Technology (MIT) and the state of Massachusetts to establish the Fraunhofer Center for Sustainable Energy Systems, or CSE. Adjacent to the MIT campus, CSE is a nonprofit, applied R&D laboratory. CSE works with industry and academia in partnerships, which include confidential co-development programs, third-party technology validation, and joint applications for grant programs. CSE focuses on building efficiency, energy device prototyping, and solar PV module testing and innovation.

On October 13, 2009, the CSE opened its first full-sized PV module innovation facility, which enables research, development, testing, and evaluation of new materials and production processes for PV solar modules. The facility – and CSE, in general – is supported by staff with expertise in R&D process development, materials, energy output, and cost reduction.

The CSE is part of Fraunhofer USA, which is a wholly owned subsidiary of German-based Fraunhofer-Gesellschaft. As one of the largest applied R&D contract organizations in the world, the Fraunhofer connection provides CSE with experience, resources, and credibility in applied research.

Goals

The objective of Fraunhofer CSE is to "help companies of all sizes get innovative clean technologies out of the lab and into the market."[10] The CSE helps accelerate the commercialization of sustainable energy technologies by assisting clients with rapid prototyping and proof-of-concept demonstrations for new energy devices. The goal of CSE's PV Module Innovation Group is to provide R&D services that enable low-cost, high-efficiency PV module systems of improved reliability.

Organization

At the leadership level, the CSE consists of an executive director, managing director, science director, and director of technical operations, as well as several official advisers. The CSE also uses a Board of Advisors to aid in directing the overall strategy and direction for the center. The board is divided into three sub-boards, including the Buildings Board, Business Board, and Solar Board. Each of these groups includes energy experts in the New England area, including MIT faculty, industry entrepreneurs and researchers, and members of the Massachusetts state government.

The founding partners for CSE include the Fraunhofer Institute for Solar Energy Systems (ISE), the Massachusetts Technology Collaborative, and National Grid. CSE has also designated a technology partner: the Fraunhofer Institute of Building Physics; and a services sponsor: Weil, Gotshal, and Manges LLP, which provides legal counsel in areas such as contract law and intellectual property.

[10] Fraunhofer CSE Web site, accessed at http://cse.fraunhofer.org/

The research connections to MIT are strong – an administrative relationship was being finalized during early 2010. This relationship, if confirmed, will result in a Fraunhofer-MIT alliance agreement that will allow the two organizations to share researchers, facilities, and other key resources on collaborative research projects. Almost half of the CSE staff are MIT alumni, and some have studied under the professors with whom they are now working.

Funding

The base funding ($21.5 million) for establishing Fraunhofer CSE was provided by Fraunhofer-Gesellschaft, the State of Massachusetts, Fraunhofer ISE, four major U.S. foundations, and National Grid. Going forward, revenue will depend more on industry contracts and competitive government contracts/grants.

Contact

Nolan Browne
Managing Director
nbrowne@fraunhofer.org
617-575-7251

http://cse.fraunhofer.org/

Interuniversity Microelectronics Centre (IMEC)

Background

Founded in 1984, the Interuniversity Microelectronics Centre (IMEC) is a nonprofit independent research center focused on nanoelectronics and nanotechnology applied to health care, smart electronics, sustainable energy, and safer transport. Headquartered in Leuven, Belgium, IMEC employs more than 1,650 people and has offices in the United States, China, and Taiwan, with representatives in Japan. IMEC's focuses in PV include silicon cells, organic cells, solar cells for concentrators and satellites, and thermophotovoltaics.

Goals

IMEC's goal in PV is to improve the performance of solar cells and to reduce their cost by a factor of 5, so that solar can provide a substantial part of the future energy demand, even if global energy demand increases by a factor of 3. For each technology group under PV, IMEC has a clearly defined aspiration or goal.

Organization

IMEC offers both IMEC Industrial Affiliation Programs (IIAP) and bilateral collaborations in PV R&D. IIAP is a business model based on the sharing of intellectual property, talent, risk, and cost. IIAP partners may send their researchers to work with IMEC researchers and residents from other IIAP partners. Under the IIAP, the sharing of technology and IP can be handled in a number of ways:

- Technology owned by IMEC can be shared with IIAP partners.
- IMEC can carry out customized R&D upon request.
- Generic results can be shared among partners in the program.
- IIAP partners can remain the owner of their own data and confidential information.

In the PV area, there is a specific IIAP program that focuses on the development of new process technologies for crystalline Si-based PV on monocrystalline Si reference substrates. More specifically, this IIAP focuses on developing highly efficient thin crystalline-silicon solar cells (< 120 μm), and thin-film crystalline-silicon solar cells.

In bilateral collaborations, agreements with industrial PV companies focus on adapting the generic results to specific materials (e.g., specific Si-substrates such as Si-ribbons) and to tune the process steps toward specific cell structures. In addition to working with industrial companies, IMEC is also collaborating with many universities and research centers.

Funding

IMEC is funded, in part, through the Flemish government, which covered about 16% of its total budget, about €270 million ($370 million) in 2009. Thus, the majority of IMEC's funding comes from industrial partners, as well as from EU and other government research grants.

IMEC recently received additional funding (€9 million or $12 million) for investing in PV-related R&D equipment through a Flemish initiative called “Vlaams Fotovoltaisch Inititiatief.” Finally, to enter the IIAP, a one-time entrance fee is paid along with an annual affiliation fee. IIAP participation is normally for a minimum of three years.

Contact

Jef Poortmans
Program Director for Photovoltaics
poortman@imec.be

www2.imec.be/be_en/home.html

SEMATECH

Background

SEMATECH is a consortium of leading semiconductor manufacturers that was founded more than 20 years ago. Its original mission was "to provide the U.S. semiconductor industry the capability of achieving a world-leadership manufacturing position by the mid-1990s."[11] Today, SEMATCH has a global focus and membership, and its current members make up about 50% of the global chip market. Through SEMATECH, members can actively partner with equipment and material suppliers, universities, research institutes, other consortia, start-ups, and governments.

Since 2008, SEMATECH has been evaluating what role it might play with respect to PV technology development. In particular, SEMATECH wants to apply insights gained from its experience facilitating collaboration in the semiconductor industry to the current challenges faced by the solar PV industry. SEMATECH has served as a primary conduit for collaboration for the semiconductor industry in a range of areas, including standards development, ESH/sustainability, new materials research, metrology capabilities, defect and cost reductions, and overall manufacturing productivity. Although many SEMATECH members and partners are already moving into PV (e.g., Applied Materials, Tokyo Electron Limited, and Taiwan Semiconductor Manufacturing Company), SEMATECH is still in an early phase of evaluating the role it would like to play in PV technology development.

Goals

SEMATECH's original focus was on advancing the U.S. semiconductor industry, but the consortium has broadened its membership focus to include international partners and expanded its technical focus to include advancing technology development and manufacturing in both the semiconductor industry and other "emerging technologies."

Organization

SEMATECH has developed a standard consortia business model, in which competitors are brought together to pool resources for solving common technology and manufacturing problems. In addition, SEMATECH established the International Technology Roadmap for Semiconductors (ITRS) to help identify common problems that can be addressed through individual and collaborative R&D efforts. The ITRS has various technology-focused teams that identify and map the technical and manufacturing challenges facing the semiconductor industry during the next 15 years. The teams are organized into an executive committee (International Roadmap Committee), sponsoring organizations, regional and international technology working groups (TWGs/ITWGs), and the SEMATECH management office. SEMATECH is interested in applying its experience with managing consortia and collaborative R&D programs to the PV industry.

[11] Browning, L.D.; Beyer, J. M.; Shetler, J. C. (1995) "Building cooperation in a competitive industry: SEMATECH and the semiconductor industry. (Special Research Forum: Intra- and Interorganizational Cooperation)" Academy of Management Journal, 01-FEB-95

Funding

Funding for SEMATECH is provided primarily through membership fees (i.e., industry) and regional government grants. SEMATECH does not offer a subgroup membership to companies interested in joining based solely on a PV focus.

Contacts

Dan Holladay
Advanced Technologies Manager
Dan.Holladay@sematech.org
512-356-7139

www.sematech.org/

SEMI PV Group

Background

The SEMI PV Group was founded in January 2008 as a special interest group of its parent organization, SEMI. It is the only not-for-profit global trade association designed to serve the PV manufacturing supply chain and to address barriers to adoption of PV technology. The SEMI PV Group represents the collective interests of its membership and it is an advocate for the PV industry as a whole. Its primary areas of focus include developing standards; facilitating road mapping and other collaborative efforts; organizing expositions and conferences (SOLARCONs, Intersolars, PVJapan); carrying out environment, health, safety, and sustainability initiatives; and working on issues related to advocacy, market intelligence, and public policy.

The SEMI PV Group's advisory committees in North America, Europe, China, Taiwan, India, and Korea include some of the largest cell and module manufacturers, and equipment and materials suppliers in the world, as well as experts in academia and government. The SEMI PV Group collaborates both globally and locally (i.e., with regional solar energy trade associations).

Goals

The SEMI PV Group's primary goal is to support continuous PV manufacturing cost reductions, to accelerate innovation in PV technology, and to improve the profitably of its members and the global PV industry as a whole. The SEMI PV Group applies to the PV industry its lessons learned from the semiconductor and other advanced technology industries. It aims to reduce costs by creating standards and optimizing the supply chain.

Organization

Participation is included with a SEMI membership – more than 30% of SEMI members are actively involved in PV manufacturing. There are many membership categories for this global group, including:

- Corporate Member - members of the PV manufacturing supply chain, including suppliers of equipment, materials, cells, modules, sub-assemblies, components, and services.
- Associate Member - companies that design, manufacture, sell, or distribute PV devices.
- Allied Member - companies and organizations that provide research, education, advocacy, or regulatory services to the PV industry.
- Affiliate Member - companies that facilitate development of PV technology and/or markets but are not specific to, or a part of, the PV manufacturing supply chain.
- Individual Member - students, retirees, consultants, or any interested individual.

Funding

SEMI is a not-for-profit trade association. Membership dues, which are based on the revenue of a company, vary from $500 to $60,000. There are also membership options for individuals.

Revenue generated through expositions helps fund programs for members and the industry, including environmental, health, and safety (EHS) advocacy, standards development, and public policy work. In 2008, SEMI revenue was about $55 million, but PV revenue was not reported as a separate category.

Contact

Bettina Weiss
bweiss@semi.org
408-943-6998

www.pvgroup.org

SolarTech

Background

SolarTech is an initiative of the Silicon Valley Leadership Group (SVLG), but has a separate board and organizational structure. SolarTech has more than 70 members that span the entire PV industry value chain and represent SolarTech's identified initiatives: Module and Balance-of-System Manufacturers, Test/Certification, Integrators/Contractors, Project Finance, Workforce, Cities, and Utilities. The organization has partnerships at the state level with the California Solar Energy Industries Association, at the federal level with the Solar Electric Power Association (SEPA)/Solar Energy Industries Association (SEIA), and also collaborates with the Interstate Renewable Energy Council, Solar America Board for Codes and Standards, and VoteSolar. SVLG has nearly 300 members, made up of a diverse set of stakeholders, with a focus on addressing major public policy issues that affect the economic health and quality of life in Silicon Valley.

SolarTech focuses locally and regionally "downstream" in the solar PV value chain, by attempting to standardize and streamline best practices, which will accelerate adoption and commercialization of solar PV and solar thermal. While working downstream, SolarTech also looks "upstream" in the value chain to accelerate time to market of new solar technologies. They accomplish this through product-introduction methodologies and partnering with Underwriters Labs and SEMI PV Group. SolarTech is well-positioned to leverage European best practices as a result of a recent "Performance Symposium" put on jointly with Intersolar NA in San Francisco. The group does not carry out lobbying activities.

SolarTech is also launching a 501(c)(3) "SolarTech Clean Energy Fund," which will provide broader funding opportunities, as well as increase its reach and influence to the broader solar community on both sides of the market transformation equation.

Goals

SolarTech's primary goal is to identify and resolve the inefficiencies inherent in the delivery of solar PV systems by lowering costs, reducing risk, and removing implementation barriers. One of its first major goals is to accelerate the adoption of solar energy by enabling solar manufacturers to certify new PV products more quickly.

SolarTech partners with relevant industry groups and companies to establish standards and metrics to streamline permitting, installation, interconnection, finance, and workforce and system performance. SolarTech also identifies workforce needs and opportunities, and helps create financial models/market mechanisms with PV developers and financing agencies. The organization's market transformation efforts stem from developing integrated business processes to ensure predictable, sustainable, manageable growth for the solar industry.

Organization

The SolarTech board includes representatives from Applied Materials Inc., SunPower, Tioga Energy, NOVA Works, PG&E, Silicon Valley Power, Santa Clara University, City of San Jose, San Jose Water Company, Underwriters Laboratories, and Real Goods Solar. SolarTech offers a forum for member organizations to work together and reduce the market barriers and

inefficiencies within PV commercialization. SolarTech has implemented a structured forum for collaboration, which includes an Annual Industry Summit (April/May), regular symposiums (for each of the six core initiatives),[12] and dedicated annual tracks through the Solar Power International conference.

Funding

SolarTech is primarily funded through grants, membership dues, and seed funding. In February 2009, SolarTech finalized an agreement for a grant of nearly $750,000 (awarded under the California Energy Commission's Public Interest Energy Research Program) to SolarTech, Santa Clara University, and Enphase. Under this grant, SolarTech will focus on developing industry best practices related to permitting, interconnection, performance, installation, and financing.

Contact

Doug Payne
SolarTech Executive Director
dpayne@solartech.org
408-768-0449

www.solartech.org/

[12] SolarTech addresses the following six core initiatives as a means of facilitating the adoption of widespread solar energy use: Workforce, Financing, Performance, Installation, Permitting, and Interconnection.

The Solar Energy Consortium (TSEC)

Background

The Solar Energy Consortium (TSEC) was founded in June 2007 in Kingston, New York. TSEC focuses on two primary areas: growing the PV industry in New York State, and increasing the efficiency of PV panels through collaborative industry/university R&D initiatives. In addition, TSEC facilitates the flow of information between solar manufacturers and research institutions, particularly universities.

Although solar energy is its primary focus, TSEC also works on fostering the development of other renewable energy technologies. TSEC acts as a solar energy adviser to New York State's public and private entities and as a prime contractor for local, state, and federal grants.

Goals

The mission statement of TSEC includes the following targets: doubling the efficiency of photovoltaic systems, reducing by half the installed cost of solar energy systems, simplifying the installation of solar energy systems, and developing unique PV forms for use in urban environments. While this mission statement lays out a long-term vision for TSEC, the primary short-term focus of TSEC is to create jobs in New York and to attract solar companies – particularly manufacturers – to New York.

Organization

TSEC is a nonprofit 501(c)(3). It has partnered with six universities and more than 60 companies in the industry. University partners include: Binghamton University, Cornell University, Rensselaer Polytechnic Institute, Clarkson University, the State University of New York at New Paltz, and the City University of New York. There are 10 members on the board of directors, which include representatives from academia, IBM, Central Hudson Gas and Electric Corp., and a few other private entities, including Wilbur National Bank and Airport Properties.

TSEC works with industry partners to understand their respective technology and product road maps and where they have gaps in R&D plans. TSEC then forges partnerships with other companies and/or universities that can help close those gaps. If necessary, TSEC will pursue any needed funding through DOE or New York State Energy Research and Development Authority (NYSERDA) competitive grants, federal earmarks from DOE or the Department of Defense (DOD), or private funding.

Funding

TSEC does not have a membership fee, and does not require payment for its services. Partnering companies cover some of TSEC’s expenses through donations. TSEC has been funded through DOE earmarks, as well as state and county grant money. In 2008, DOE allocated an earmark of approximately $1.47 million to TSEC; about $1 million of that went to Prism Solar to build a facility in New York.

TSEC received a few hundred thousand dollars from the county, in addition to a $750,000 state grant. This grant was used to buy testing equipment that can be used by solar companies within TSEC's "cluster" to improve their manufacturing processes. Companies can borrow the equipment – also known as TSEC's "virtual lab" – for free.

Contact

Vincent Cozzolino
President / CEO
vincent.tsec@gmail.com
845-656-1334

http://thesolarec.org/

Solar Technology Acceleration Center (SolarTAC)

Background

The Solar Technology Acceleration Center (SolarTAC) is a private, member-based solar research facility in Aurora, Colorado. The SolarTAC provides a facility where the solar industry can test, validate, and demonstrate near-market and advanced solar technologies. The founding members of SolarTAC include Xcel Energy, SunEdison, and Abengoa Solar; sponsoring members include NREL and the Electric Power Research Institute. SolarTAC encourages all types of research (i.e., proprietary, collaborative, and public), and members will be performing various types of research and demonstration projects at the site. The Midwest Research Institute (MRI) manages and operates SolarTAC for the founding members. SolarTAC maintains close relationships with key industry organizations, such as the Colorado Renewable Energy Collaboratory.[13] SolarTAC, the largest private test facility for solar technologies in the United States, has developed 74 acres outside Aurora, and is available for testing both PV and concentrating solar power (CSP) technologies; testing and evaluation of access to the grid can also be conducted at SolarTAC. The facility has more than 300 additional acres for expansion.

Goal

"SolarTAC's mission is to increase the efficiency of solar energy products and rapidly deploy them to the commercial market."[14]

Organization

SolarTAC is managed and operated by the Midwest Research Institute. Membership is open to utility companies, solar technology developers, and major end users of solar energy systems, including equipment suppliers. There are two levels of membership: founding and sponsoring. Founding members have a permanent seat on the Executive Board and Scientific Advisory Board, a full vote in planning the build-out of the test site, a five-acre tract of land for proprietary tests, and several other benefits (including those listed for sponsoring members). Sponsoring members have representation on the Executive Board and a permanent seat on the Scientific Advisory Board.

Funding

SolarTAC is funded by membership fees. Founding members pay a minimum investment of $500,000 annually for the first three years, and $100,000 a year for membership fees thereafter. Sponsoring members pay a $100,000 annual membership fee from the date of becoming a member (small businesses pay $25,000). SolarTAC also pursues additional funding support through state and federal channels.

Contact

Dustin Smith, Executive Director
dtsmith@mriresearch.org
303-739-7649

www.solartac.org/

[13] The Center for Revolutionary Solar Photoconversion (CRSP), listed at the beginning of this document, is a Colorado Renewable Energy Collaboratory research center.
[14] SolarTAC Web site, accessed at http://www.solartac.org/About/Default.aspx

SVTC Solar

Background

Founded in June 2008, SVTC Solar is the newest business unit of SVTC Technologies, a product-development services company. Through facilities in San Jose, California, and Austin, Texas, SVTC maintains $100 million worth of fabrication facilities that semiconductor manufacturers can leverage to develop ideas into production-ready products. The company focuses on novel process development and is supported by investors Tallwood Venture Capital and Oak Hill Capital Partners, who purchased it in 2007. Also in 2007, SVTC merged with SEMATECH's Advanced Technology Development Facility, which doubled its capabilities and capacity.

SVTC Solar plans to implement a business model similar to the one used by SVTC for the semiconductor industry, but optimized for the development of PV products. SVTC Solar does not have the tools to implement full-scale manufacturing process development, but several companies are already using their complementary metal–oxide–semiconductor (CMOS) facilities for solar product development.

Goals

SVTC Solar's primary goal is to provide PV companies with the resources to develop and commercialize differentiated solar cell technologies and provide pilot-scale manufacturing capabilities to improve each company's commercialization opportunities. The company strives to maintain a reputation of high IP security for its development customers.

Organization

SVTC Solar fosters partnerships with an array of service providers and suppliers within the photovoltaic industry. In particular, the company works with vendors that offer equipment, engineering, testing, failure analysis, and certification resources. It has a key partnership with Roth & Rau AG, a global supplier of technology and production equipment for the PV industry, which gives SVTC Solar access to equipment for research and development in crystalline silicon solar cell manufacturing. SVTC, its parent company, provides additional support with facilities and personnel.

Funding

SVTC Technologies is a for-profit company that is supported through fee-for-service applications as well as capital raised by existing investors. SVTC Solar is partnering with many equipment companies and seeking funding to establish the needed facilities for its business. SVTC continues to seek government support to help launch the operations of SVTC Solar.

Contact

Steve Empedocles
Director of Business Development
Steve.empedocles@svtc.com
650-776-7089

www.svtc.com/solar

TUV Rheinland Photovoltaic Testing Laboratory (PTL)

Background

TÜV Rheinland Photovoltaic Testing Laboratory (PTL) is a spin-off company from the 16-year-old Photovoltaic Testing Laboratory (PTL) of Arizona State University. Launched in late 2008, TÜV Rheinland PTL is a facility for PV technology testing in Tempe, Arizona, and is a partnership between TÜV Rheinland ($1.5 billion USD provider of independent testing, assessment, and certification services for industry) and Arizona State University (ASU). TUV Rheinland PTL is the largest testing laboratory in the world with a focus on PV module testing, PV component testing, inverter testing, and system testing/monitoring.

Goals

TÜV Rheinland PTL's mission is "to bring technology, expertise, and professionalism to the performance, safety, and reliability testing for the energy marketplace."[15] The company pursues activities in five areas: developing global industry expertise; involvement in U.S. and international standards development; establishing partnerships with valued clients; providing world-class testing facilities, staff, and services; and maintaining a global network of state-of-the-art laboratories.

Organization

TUV Rheinland PTL is a joint venture company between TUV Rheinland and ASU. Dr. Mani Tamizhmani is both a professor at ASU and president of TUV Rheinland PTL. TUV Rheinland can tap into ASU students and research expertise, while ASU gets access to TUV Rheinland resources and contacts in TUV's more than 1,000 client companies. Of the 49 people working at TUV Rheinland PTL, 29 are current ASU students.

Funding

TUV Rheinland PTL is a for-profit business, providing a paid-for service to companies.

Contact

Mani G. TamizhMani
President of TUV Rheinland PTL
Professor of Arizona State University
GTamizhMani@tuvptl.com; Manit@asu.edu
480-584-7296

www.tuvptl.com/index.htm

[15] TÜV Rheinland PTL Web site, accessed at http://www.tuvptl.com/mission.html

References

National Academy of Sciences (NAS). (2009). "State and Regional Innovation Initiatives: Partnering for Photovoltaic Manufacturing in the United States," National Academy of Sciences, Washington, D.C., July 29, 2009. Presentations can be found at http://sites.nationalacademies.org/PGA/step/PGA_052440

The following are highlighted presentations from the NAS event listed above:

Sites, J. (2009). "Photovoltaic Manufacturing in the United States: A University Perspective," Colorado State University, July 29.

Empodocles, S. (2009) "SVTC Solar: A Photovoltaic Product Development Center," SVTC Solar, July 29.

Browne, N. (2009) "Industry-University Partnerships for Photovoltaics," Fraunhofer Center for Sustainable Energy Systems, July 29.

Polcari, M.R. (2009) "The SEMATECH Model: Potential Applications to PV," SEMATECH, July 29.

Sumney, L.W. (2009) "Semiconductor Research Corporation: A Proven Means to Fund Relevant Research," SRC, July 29.

Weiss, B. (2009) "Accelerating Growth and Cost Reduction in the PV Industry," SEMI PV, July 29.

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14. ABSTRACT *(Maximum 200 Words)*
As the U.S. Department of Energy's (DOE's) Solar Energy Technologies Program prepares to initiate a new cost-shared research and development (R&D) effort on photovoltaic (PV) manufacturing, it is useful to review the experience to date with consortia focused on PV R&D, manufacturing, and testing. Analysts gathered information for this report by conducting interviews and accessing Web sites of 14 U.S. consortia and four European consortia, each with either a primary focus on or an emerging interest in PV technology R&D, manufacturing, or testing. They collected additional input from several workshops held by the DOE and National Academy of Sciences (NAS) in 2009, which examined the practical steps – including public-private partnerships and policy support – necessary to enhance the United States' capacity to competitively manufacture photovoltaics. This report categorizes the 18 consortia evaluated into three groups: university-led consortia, industry-led consortia, and manufacturing and testing facilities consortia. The first section summarizes the organizations within the different categories, with a particular focus on the key benefits and challenges for each grouping. The second section provides a more detailed overview of each consortium, including the origins, goals, organization, membership, funding sources, and key contacts. This report is a useful resource for stakeholders interested in PV manufacturing R&D.

15. SUBJECT TERMS
NREL; energy analysis; Robert Margolis; Charlie Coggeshall; solar energy; solar consortia; photovoltaics; PV; National Academy of Sciences; Center for Revolutionary Solar Photoconversion; CRSP; Energy and Environmental Technology Applications Center at the College of Nanoscale Science and Engineering; E2TAC; Institute of Energy Conversion: IEC; Semiconductor Research Corporation; SRC; Silicon Solar Consortium Research Center, SiSoC; SolarFocus; Wright Center for Photovoltaics Innovation and Commercialization; PVIC; CPV Consortium; Crystal Clear; Fraunhofer-CSE; Interuniversity Microelectronics Centre; IMEC; SEMATECH; SEMI PV Group; SolarTech; The Solar Energy Consortium; TSEC; Solar Technology Acceleration Center; SolarTAC; SVTC Solar; TUV Rheinland Photovoltaic Testing Laboratory

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