Solar Energy Technologies Program Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project Title: Fully Integrated Building Science Solutions for Residential and Commercial Photovoltaic Energy Generation

Program Team : PV

Presenter (PI) : Michael Mills, Ph.D.
Program Manager: Pat Nugent

Organization: Dow Chemical / Dow Solar

Contact Info: MEMills@dow.com

Date: May 26, 2010

"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that."

— Thomas Edison

The year – 1931.

Project Title: Fully Integrated Building Science Solutions for Residential and Commercial Photovoltaic Energy Generation

Program Team : PV

Presenter (PI) : Michael Mills, Ph.D.
Program Manager: Pat Nugent
Organization: Dow Chemical / Dow Solar
Contact Info: MEMills@dow.com
Date: May 26, 2010

Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Timeline

- Project start date: Aug. 2007
- Project end date: Oct. 2011
- Percent complete: ≈ 65%

Budget

- Total project funding - $19,648,607
  - DOE share - $9,824,303
  - Contractor share - $9,824,304
- Funding received in FY09
  - $251,520
- Funding for FY10
  - $3,582,102

Barriers

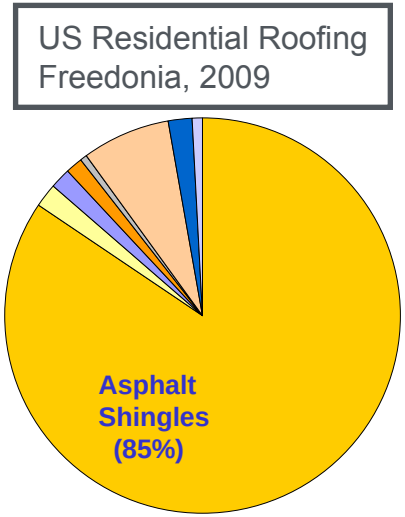
- Barrier materials for CIGS
- Decreasing cost and complexity for residential installations
- Development of channel partners for high penetration of PV for residential installations

Partners/Suppliers

- Dow Solar - Project lead
- Global Solar Energy
- National Home Builders
  - Lennar
  - Pulte

Challenges, Barriers or Problems

- Challenges, Barriers or Problems for this Project Include:
  - Barrier materials for CIGS
    - Cost effective, flexible barrier that meets ALL requirements
    - Stable supplier base
  - Installation of Roof Top Solar
    - High cost, multiple trades required
  - Low penetration into residential market
    - Underdeveloped market channels to serve the residential solar roofing market
- Overcoming these Barriers Allows For:
  - Low cost, widely available barrier materials for product development in multiple and affordable building product form factors
  - Significant cost reductions in installation costs from simplifying installation and utilizing the hundreds of roofing contractors in the US as solar roofing installers
  - A product that integrates with asphalt shingle roofs which represent 85% of North American residential roofs



Objectives, Approach & Impact

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project Goal

A full line of cost effective PV containing Building Products

Project Objectives

1. Functional prototype shingle
2. Hermetic CIGS packaging
3. Shingle product certification by UL, Miami-Dade, IEC as PV and roofing product
4. Validated installed system

Performance Towards Project Objectives

Objectives for the Past Year

- Barrier work
- Reduction of Installation Costs
  - Demonstrated lower installation costs and decreased complexity with several residential roof top installations
  - Developed draft training modules and trained roofing contractors on installation in approximately 1 hour
- Solar Shingle enhancements and modifications to continually improve aesthetics, shingle safety & performance from both a power output perspective as well as product lifetime
- Education and engagement of more than 50% of the top ten production builders in the US
  - Multiple demonstration builds in development through out the US residential building community
- Stage Gate Deliverables
  - Functional shingle tested and evaluated for performance in lab and outdoor roof
  - CIGS packages with Dow encapsulant delivered for accelerated long-term stability tests
  - Shingle analog form factor BIPV package for UL and IEC standardized tests
  - Validation of integrated shingle circuit design to demonstrate how interconnect occurs simultaneously with shingle installation. Performance tests conducted.

1) Functional Prototype Shingle

- Objective
  - Successfully designed and develop the BIPV shingle to meet initial and evolving design criteria from continuous VOC activity
- Approach
  - Combined design, FEA modeling, prototyping, and continuous improvement to deliver current product
- Impact
  - Previewed at International Builder's Show in Las Vegas, NV in January 2010

2) Hermetic CIGS packaging

- Objective
  - Determined engineering design criteria for sufficient hermeticity to enable a > 20 year BIPV product based on CIGS PV material
- Approach
  - Evaluate internal and and external development and commercial flexible barrier technology against engineering design criteria determined in accelerated reliability testing and modeled for > 20 year product lifetimes. Partner with flexible barrier manufacturer(s) to develop a cost effective product which incorporates ALL requirements
- Impact
  - Enable a diversity of BIPV product form factors with > 20 year life expectancies

3) Product certification by UL, Miami-Dade and IEC as PV and roofing product

- Objective
  - Fully certified BIPV shingle product which integrates with asphalt shingle residential roofs
- Approach
  - Fully engage with Certification Organizations at regular frequency
  - Participate on Code & Standards Technical Advisory Committees
    - Solar ABCs Industrial Advisory Committee
    - ICC & ICC-ES (building codes addressing BAPV & BIPV)
    - Drafting IEC BIPV standard
- Impact
  - Reduced product introduction timeline
  - Guidance to building code official & AHJs for BIPV products

4) Validated Installed System

- Objective
  - Validate easier, lower cost installation of complete system
  - Validate system level design and performance
- Approach
  - Design system incorporating local factors
  - Provide total system kit
  - Train roofing installers with installation manual
  - Monitor and inspect results
- Impact
  - Allows for continuous improvement in installation procedure, product design, and system performance and lifetime

Collaborations

- Global Solar Energy (GSE) is our preferred supplier of CIGS material on stainless steel substrate for the Dow POWERHOUSE™ Solar Shingle scheduled for commercial launch in 2011. GSE has continued to deliver on their Efficiency Roadmap and is currently delivering some cell strings with efficiencies in excess of 11%.
- Pulte / Lennar represent our preferred National Builders who are assisting in the development of the most effective rollout and distribution to ensure rapid market penetration beginning in 2011.
- Dow has recently hosted a PV Reliability Summit to address the long-term reliability necessity for warranty. Experts from Sandia National Labs, Quality Associates, ReliaSoft, Stanford University, Iowa State University, University of Maryland – CALCE were all in attendance.
- Dow has formed a “Solar Advisory Council” to broaden our insights into the Solar Industry.

Accomplishments / Progress / Results

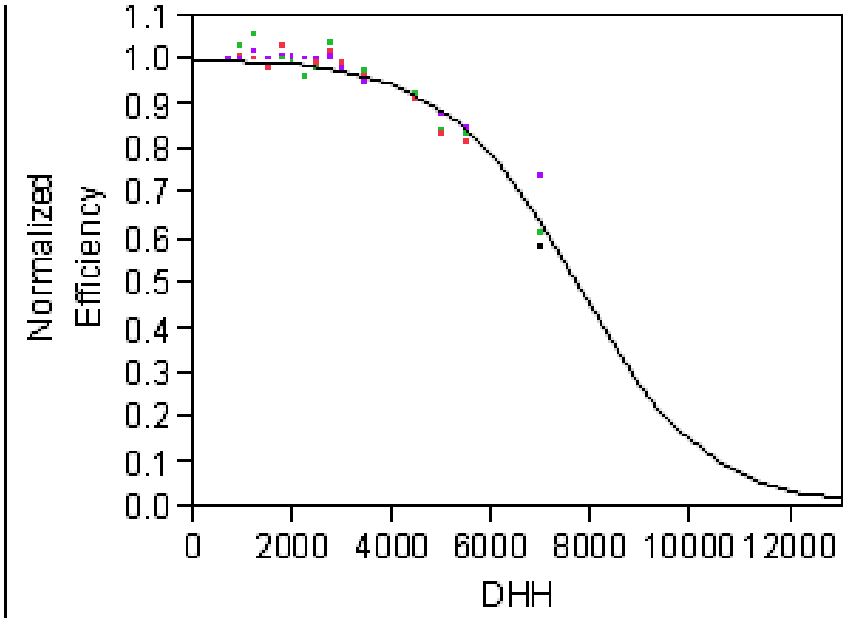
- Task 1 – Functioning Prototype shingle
  - Over 10,000 functioning prototype shingles have been produced along with required system integration pieces.

Rev A → Rev G

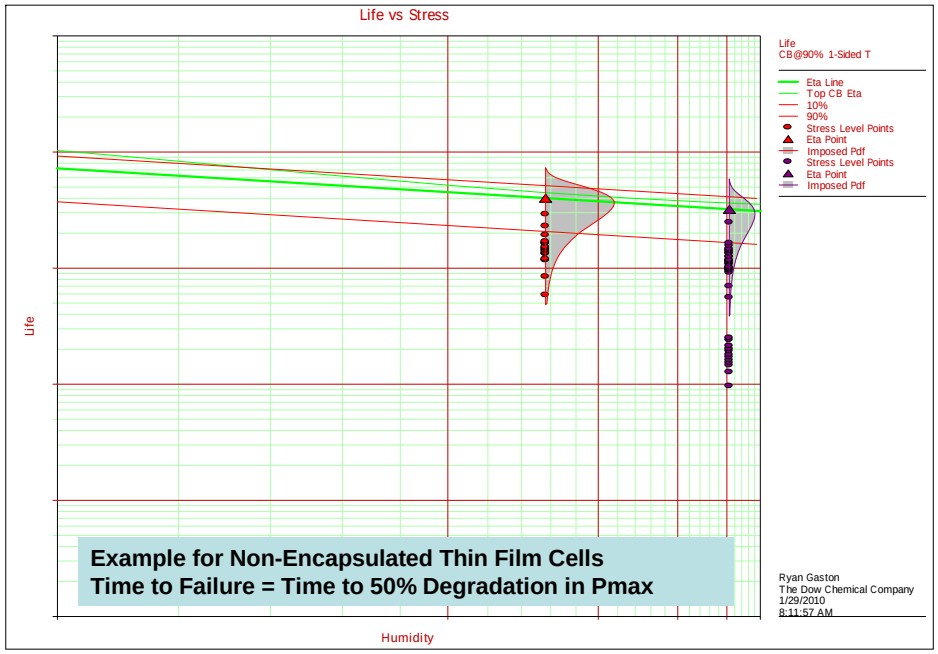
Accomplishments / Progress / Results

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Task 2 – Hermetic CIGS Packaging
  - Fundamental modeling of CIGS degradation with emphasis on acceleration factors for single and multi-mechanistic processes.



V.A. Kuznetsova, R.S. Gaston, et. al., "Photovoltaic Reliability Model Development And Validation," 34th IEEE PVSC, Philadelphia, PA, 2009.

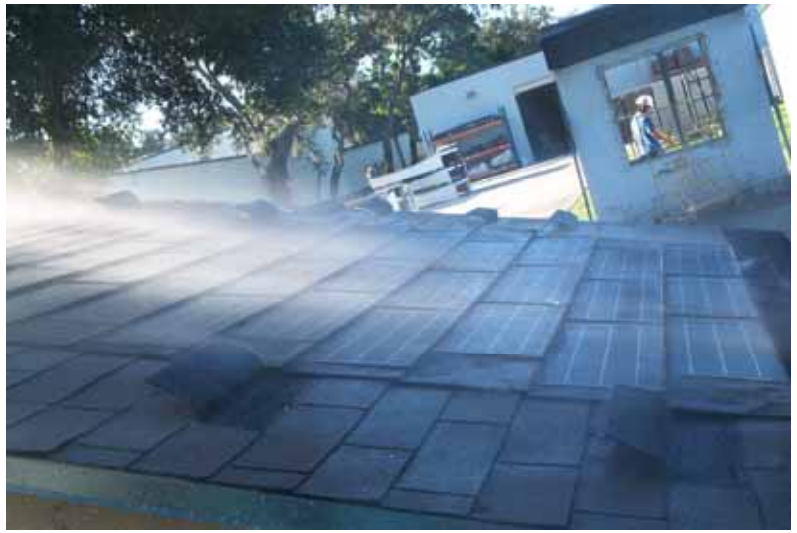


Lifetime vs Humidity

Gaston, R., "'Designing for Reliability: Thin-Film Building Integrated Photovoltaic Modules", DOE Reliability Photovoltaic Module Reliability Workshop, Golden, CO, 2010.

Accomplishments / Progress / Results

- Task 3 – Shingle Product Certification
  - UL, Miami-Dade & IEC certification for both PV and roofing attributes are in-progress
  - Installation guide developed



Accomplishments / Progress / Results

- Task 4 – Marketing and Deployment

  - DOW™ POWERHOUSE™ Solar Shingles installed on Vision Zero home in partnership with Cobblestone Builders
  - First permanent residential installation of the solar shingle
  - First time testing the installation of Dow Solar electrical design package utilizing full connection and working with local electrical inspectors
  - Michigan's first on grid

    Net Zero Energy home

Budget Status and Potential for Expansion

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Total project funding by source.
  - Phase I – Aug 07 - Oct 08
  - Phase II – Nov 08 – Current

	Phase I Plan	Phase I Actual	Phase II Plan	Phase II Actual thru April 2010
Dow	$2,687,845	$2,830,982	$3,556,381	$4,705,605
Global Solar	$153,451	$18,389	$25,722	$25,722
Federal (DOE)	$2,841,296	$2,841,296	$3,582,102	$3,582,102
Labor Hours	28,630	30,897	37,945	40,066
Total	**$5,682,592**	**$5,698,743**	**$7,164,205**	**$8,313,429**

- Additional funding would be used for development of an expanding portfolio of BIPV products

Future Plans (FY 2011 and beyond)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Dow Solar awarded up to $140 million for DOW POWERHOUSE™ Solar Shingle commercial facility from the Michigan Economic Development Corporation
- Dow is scaling up to more than 200 megawatts of capacity by 2015 from this first commercial facility
- Dow and the California Institute of Technology have a multi-year research collaboration aimed at developing the next generation of ultra low cost, high efficiency photovoltaic materials. Based on earth abundant elements, these new PV materials will further reduce the cost of the DOW POWERHOUSE™ Solar Shingle.

Summary

- Beta-version of Dow Solar Shingle has been designed to incorporate many of the learning's from code testing, installer trials, Dow Solar Advisory Council, and recent Dow Reliability Summit.
- Extensive outdoor testing (Midland, Miami, Phoenix) coupled with accelerated and highly accelerated testing continue to support the reality of a 30 year useful product power output life.
- Targeted product introductions (IBS 2010) has confirmed demand for a “true aesthetically pleasing” BIPV product capable of significantly impacting the distributed power generation in North America.
- Dow is investing engineering resources now to scale the manufacturing capacity to meet the market demand for the Dow POWERHOUSE™ shingle.

Thank You!

Supplemental Slides

Project Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

1. Initiation Date: August 2007
2. Original Expected Completion Date: August 2010
3. Current Expected Completion Date: October 2011
4. Reasons for Delay
   A. Did not initially pass a milestone in Phase1 and had to repeat testing

Project Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Milestones for FY10 and FY11

1. Demonstrate BIPV shingle form factor package using cells of >9% average efficiency capable of meeting standardized UL and IEC safety and long term reliability.
2. Demonstrate BIPV (>9% cell production average efficiency) shingle system performance and reliability on residence.
3. Demonstrate BIPV (>9% cell production average efficiency) shingle manufacturing system performance and reliability.

Go/no-Go's for FY10 and FY11

1. End of Phase 1: Based upon shingle form factor BIPV package at 9% cell production average efficiency capable of meeting standardized UL and IEC safety and long-term tests.
2. End of Phase 2: Based upon demonstrated BIPV (9% cell production average efficiency) shingle system performance and reliability in actual in-service conditions simulating a small residential installation.

Responses to Previous Year Reviewers' Comments

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- If yours is an on-going project that was reviewed last year, address one to three significant questions/ criticisms/recommendations from the previous year's reviewers' comments.

Not Applicable – Project was on hold last year

Publications and Patent Applications

Peer Reviewed Publications:

1. Gaston, R., Feist, R., et al. “Product reliability and thin-film photovoltaics”, Reliability of Photovoltaic Cells, Modules, Components, and Systems II , Proceedings of SPIE 7412 (2009). pp. 74120N-74120N-15
2. V.A. Kuznetsova, R.S. Gaston, et. al., “Photovoltaic Reliability Model Development And Validation,” 34th IEEE PVSC, Philadelphia, PA, 2009.
3. Gaston, R., “'Designing for Reliability: Thin-Film Building Integrated Photovoltaic Modules”, DOE Reliability Photovoltaic Module Reliability Workshop, Golden, CO, 2010.
4. Schleuter, C, “Solar Roofs and Distributed Generation”, Advancing Renewables in the Midwest, June 3, 2009

Publications and Patent Applications

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Patent Applications Filed:

1. May 2009 - IMPROVED PHOTOVOLTAIC DEVICE AND METHOD
2. May 2009 - IMPROVED METHOD FOR ENCAPSULATING THE EDGE OF A FLEXIBLE SHEET
3. May 2009 - OPTOELECTRONIC DEVICE
4. May 2009 - CONNECTOR DEVICE FOR BUILDING INTEGRATED PHOTOVOLTAIC DEVICE
5. May 2009 - PHOTOVOLTAIC DEVICE ASSEMBLY AND METHOD
6. May 2009 - A MULTI-LAYER LAMINATE STRUCTURE AND MANUFACTURING METHOD
7. May 2009 - SYSTEM FOR INSTALLATION OF PHOTOVOLTAIC DEVICES ON A STRUCTURE
8. July 2009 - A DIRECT MOUNTED PHOTOVOLTAIC DEVICE WITH IMPROVED ADHESION AND METHOD THERE OF
9. Sept. 2009 - BUILDING INTEGRATED PHOTOVOLTAIC HAVING INJECTION MOLDED COMPONENT
10. Nov. 2009 - A DIRECT MOUNTED PHOTOVOLTAIC DEVICE WITH IMPROVED FRONT CLIP
11. Nov. 2009 - A DIRECT MOUNTED PHOTOVOLTAIC DEVICE WITH IMPROVED SIDE CLIP
12. Mar. 2010 – AN IMPROVED PHOTOVOLTAIC DEVICE
13. 5 very new submissions that will be reported shortly