2008 Solar Annual Review Meeting

Session: (CIGS)
Company or Organization: (The Dow Chemical Company)
Funding Opportunity: (SAI TPP)

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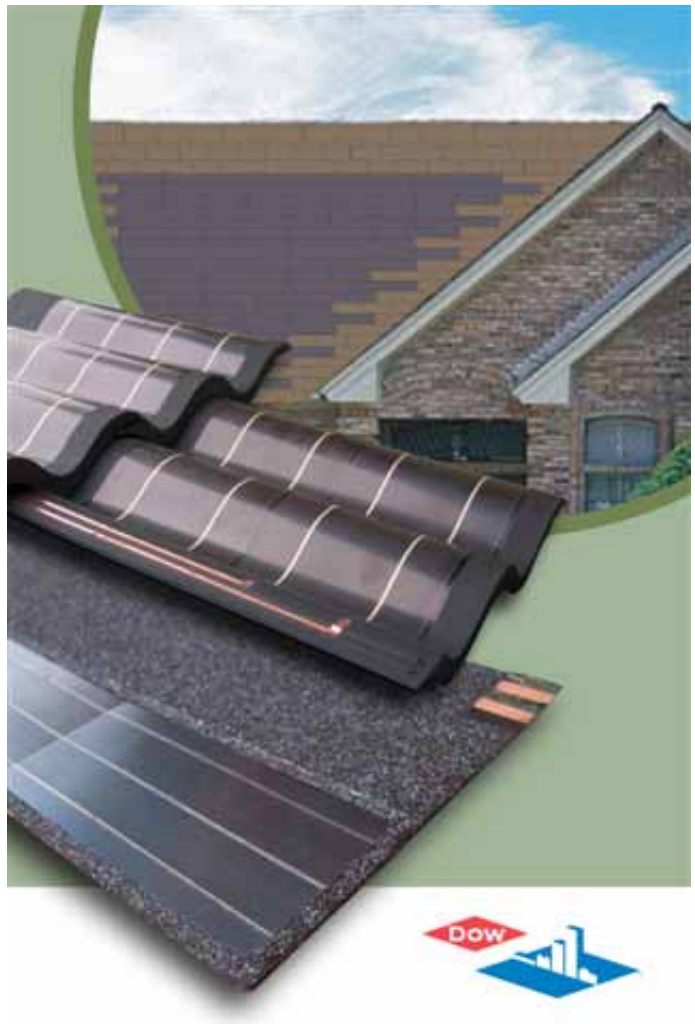
Dow Chemical Company – SAI TPP

Goal: A full line of cost effective PV Containing Building Products

SAI Team Members:

Dow Building Solutions
Fronius
Global Solar Energy
IBIS Associates
Lennar Corporation
Prost Builders, Inc
Pulte Homes, Inc.
University of Delaware - IEC
Southern California Edison



Budget and Solar America Initiative Alignment

Project Start Date: October 1, 2007

FY 2008 Budget: $ 5.7MM **Spent:** $2.3MM

FY 2009 Budget: $ 6.9MM

FY 2010 Budget: $ 7.1MM

This project supports the SAI Initiative by providing a route to LCOE grid parity for residential and commercial rooftop PV installations

Planned Work & Accomplishments (Since Project Start - September 2007)

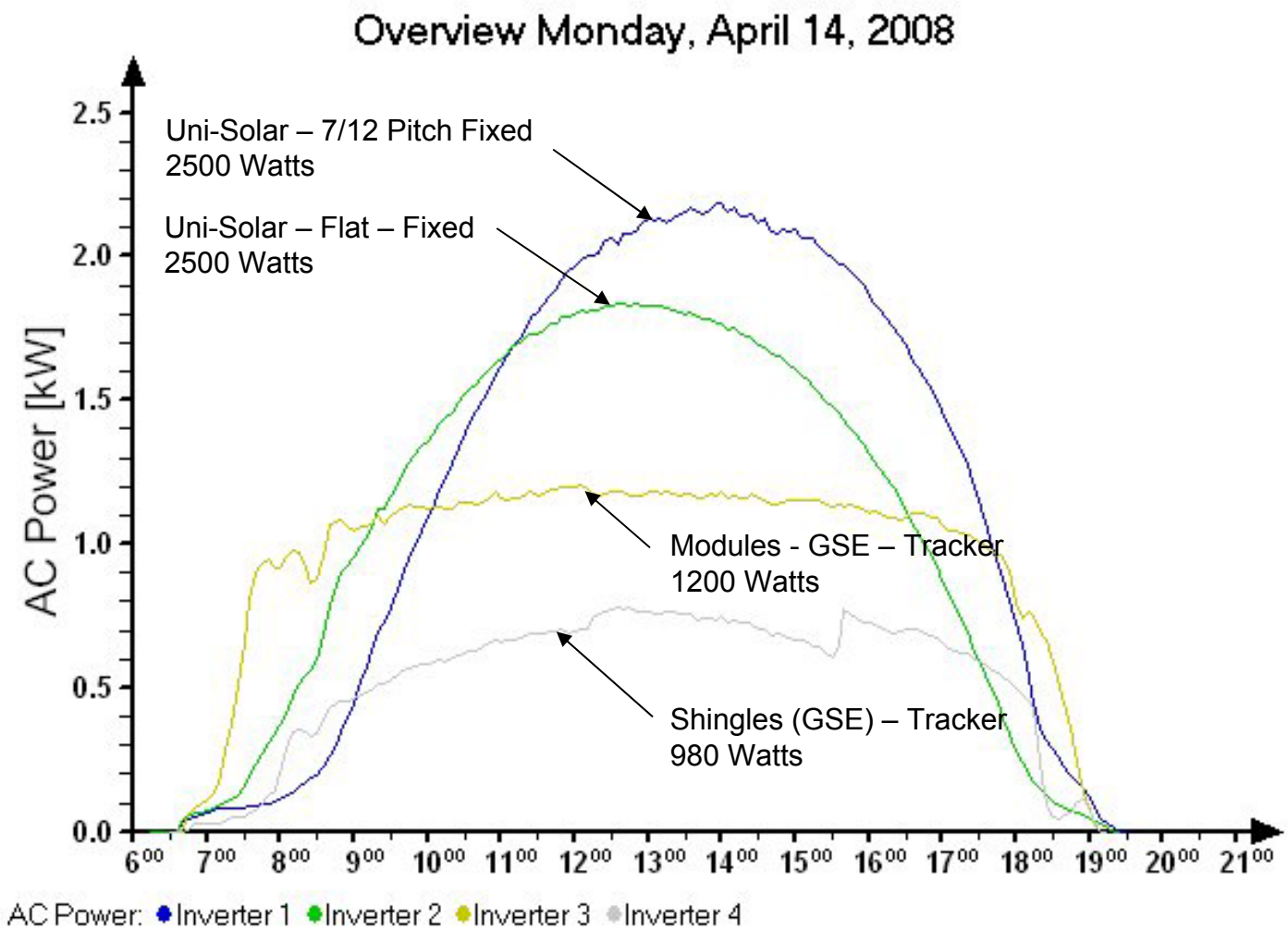
1. **Evaluated 50+ CIGS Packaging Material Options**
2. **Designed & manufactured “analog” BIPV shingles**
3. **Designed pilot line, initiated construction, specified and ordered equipment for 1 MW manufacturing pilot line**
4. **Purchased and installed extensive suite of testing equipment**
5. **Built & Installed CIGS Module & Shingle Arrays**

Solar Arrays – Thin Film α-Si - Uni-Solar (Pre-SAI)

Solar Array – Thin Film CIGS (GSE)

GSE CIGS – Modules & Shingles

Example Power Output – 4 Arrays



Planned Work & Accomplishments (Since Project Start - September 2007)

1. Evaluated 50+ CIGS Packaging Material Options
2. Designed & manufactured “analog” BIPV analog shingle
3. Designed pilot line, initiated construction, specified and ordered equipment for 1 MW manufacturing pilot line
4. Purchased and installed extensive suite of testing equipment
5. Built & Installed 1 KW Shingle Array
6. **Conducted VOC (Voice of Customer) interviews at the National Home Builder’s Show.**
7. **Conducted phone conference interviews with 15 utility companies in United States**
8. **Completed market adoption study and scale up feasibility plan**

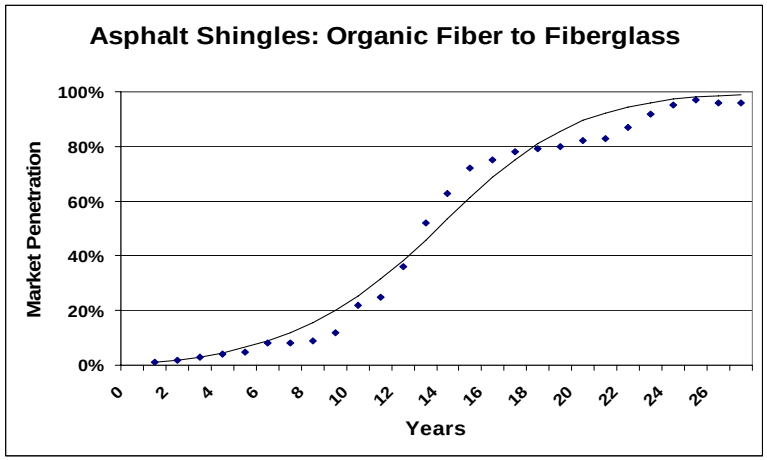
Market Adoption Analysis

Forecast the growth of BIPV in residential roofing based on "technical replacement model"

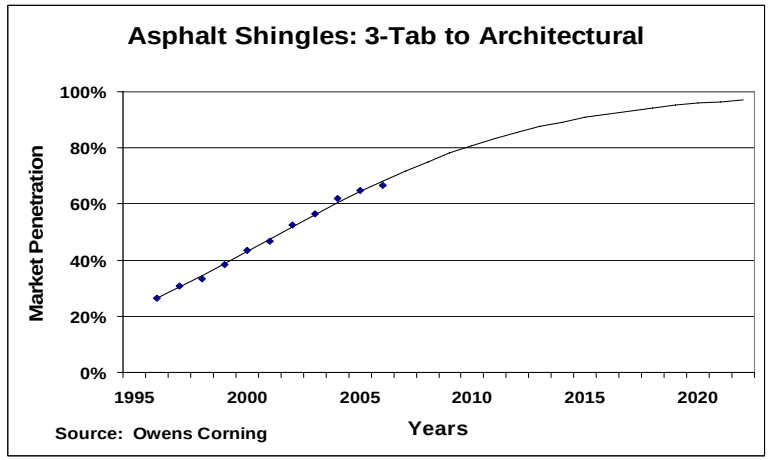
- ✓ Defensible demand forecasts
  - Expressed as power (MW), area (sq-meter), and money (nominal $)
- ✓ State-wise or regional segmentation
  - Scalable to other regions
- ✓ Rational economic behavior
- ✓ *Bona fide*, citable data sources
- ✓ 30 year horizon, 15 year focus

Market Penetration - Based on four historical substitution analogs:

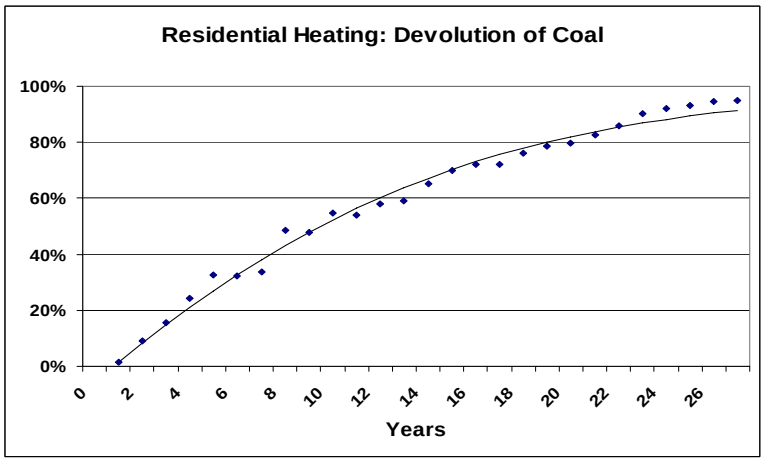
Fiberglass for organic fiber in asphalt shingles



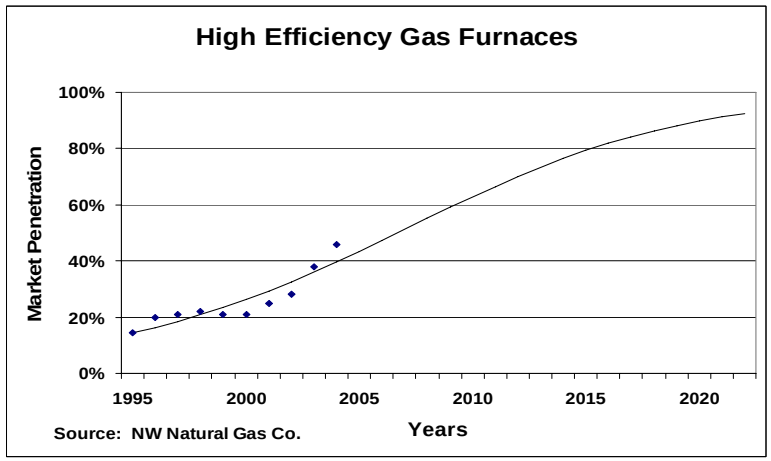
Architectural for 3-tab shingles in roofing



Devolution of coal in residential heating



High efficiency gas furnaces



Market Adoption Analysis

$$Demand_t = Technical\ Potential_t \times Penetration_t \times Acceptance_t$$

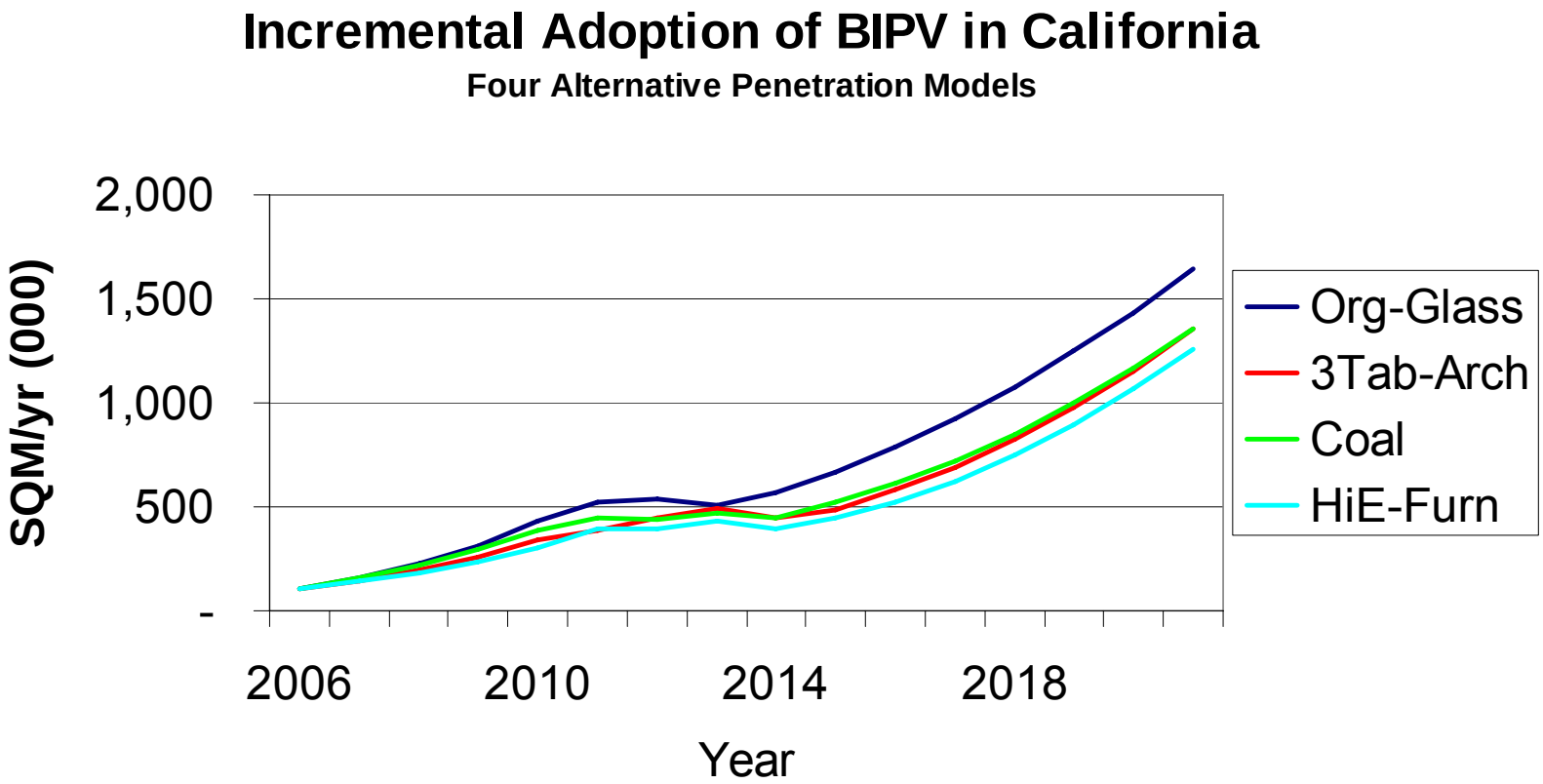
- ✓ Technical Potential
  - What is the maximum possible market size, based on physical limitations?
- ✓ Penetration
  - How fast will the market grow, based on historical analogies?
- ✓ Acceptance
  - How widely will it be accepted, based on economic payback?

Each factor varies in time and geography

Computed stepwise year-to-year

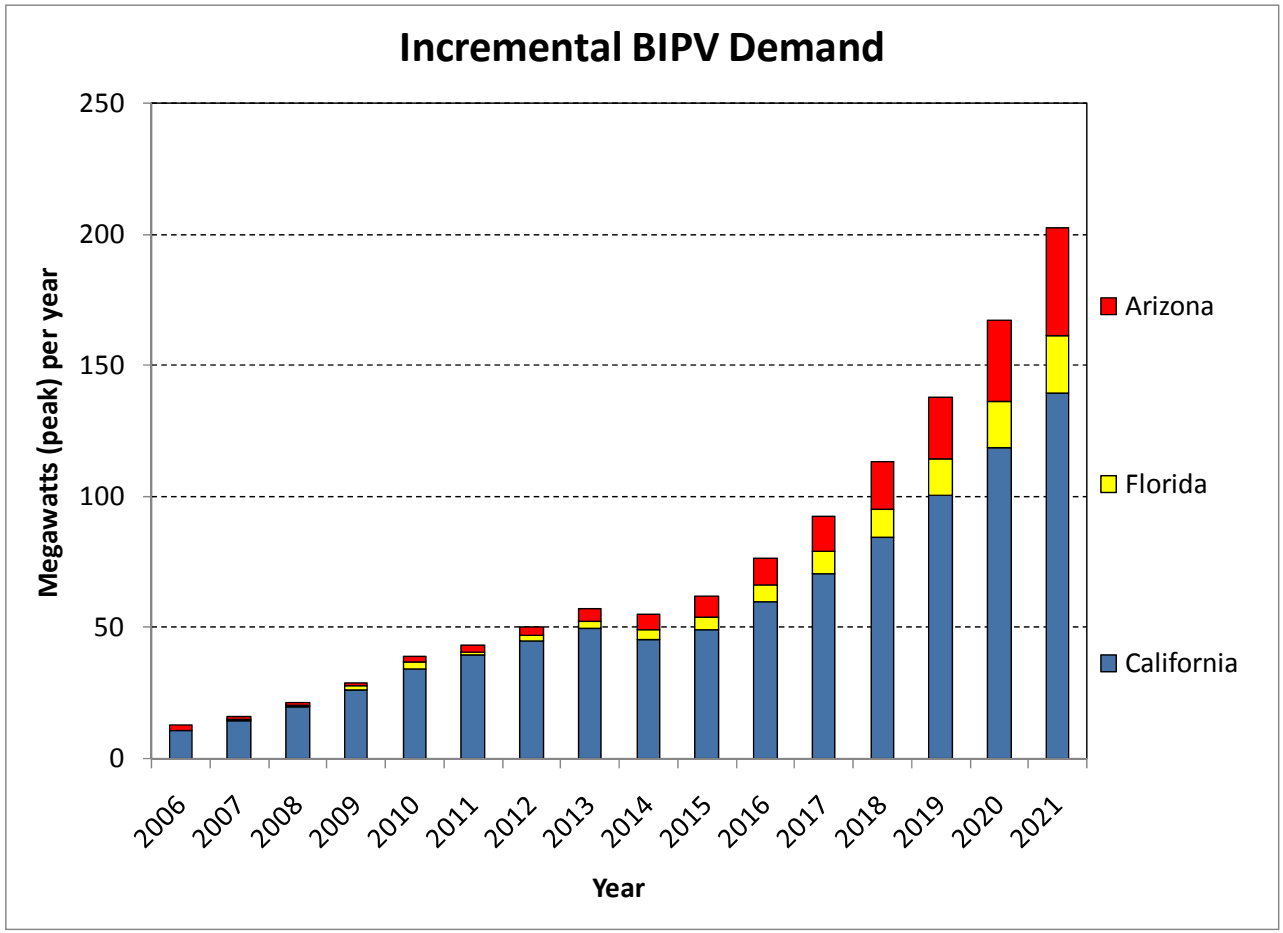
- ✓ 2006 baseline year

Comparison of Penetration Models



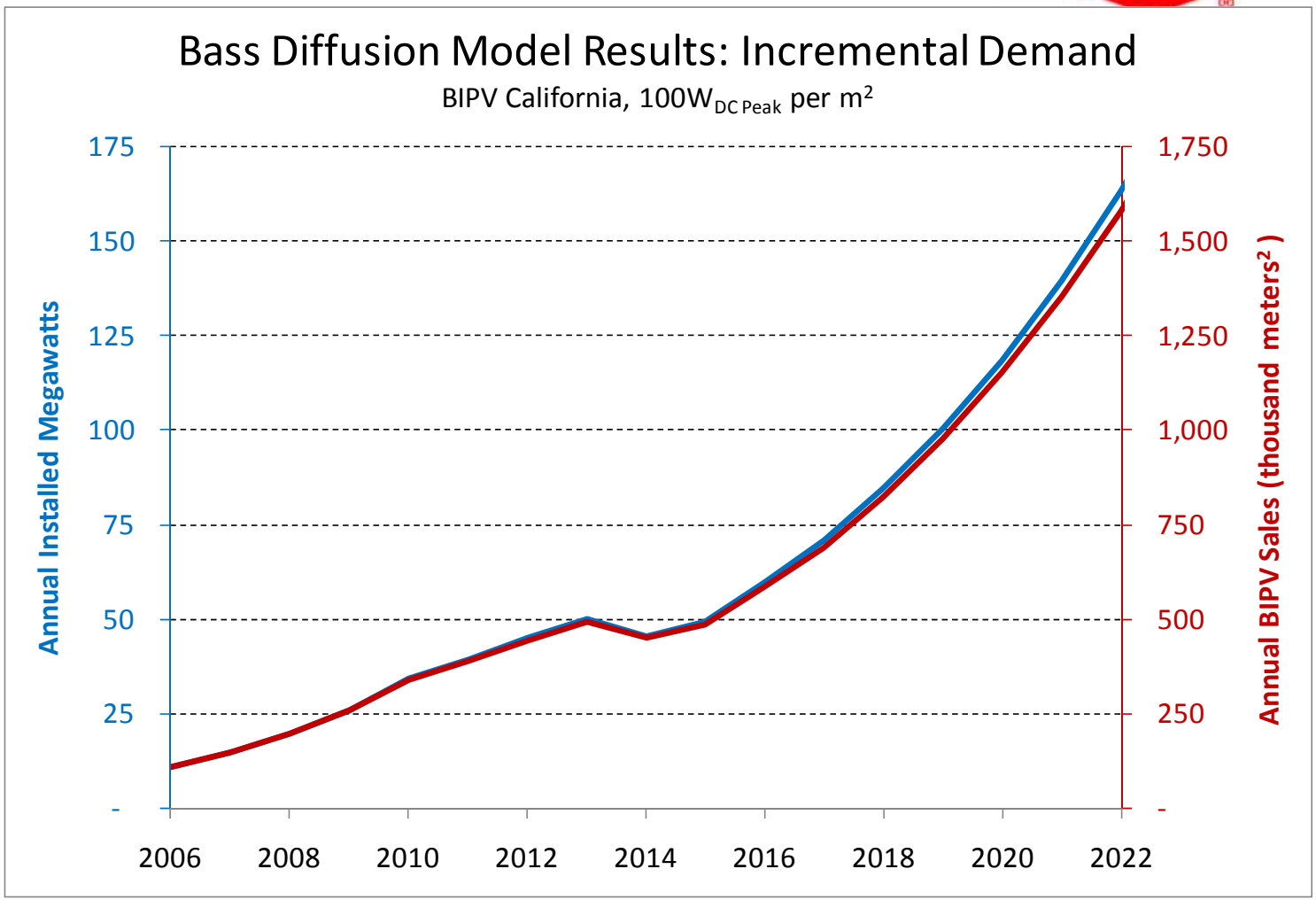
Architectural shingles selected as baseline for subsequent analyses

Summary of 3 Key States - Area Values



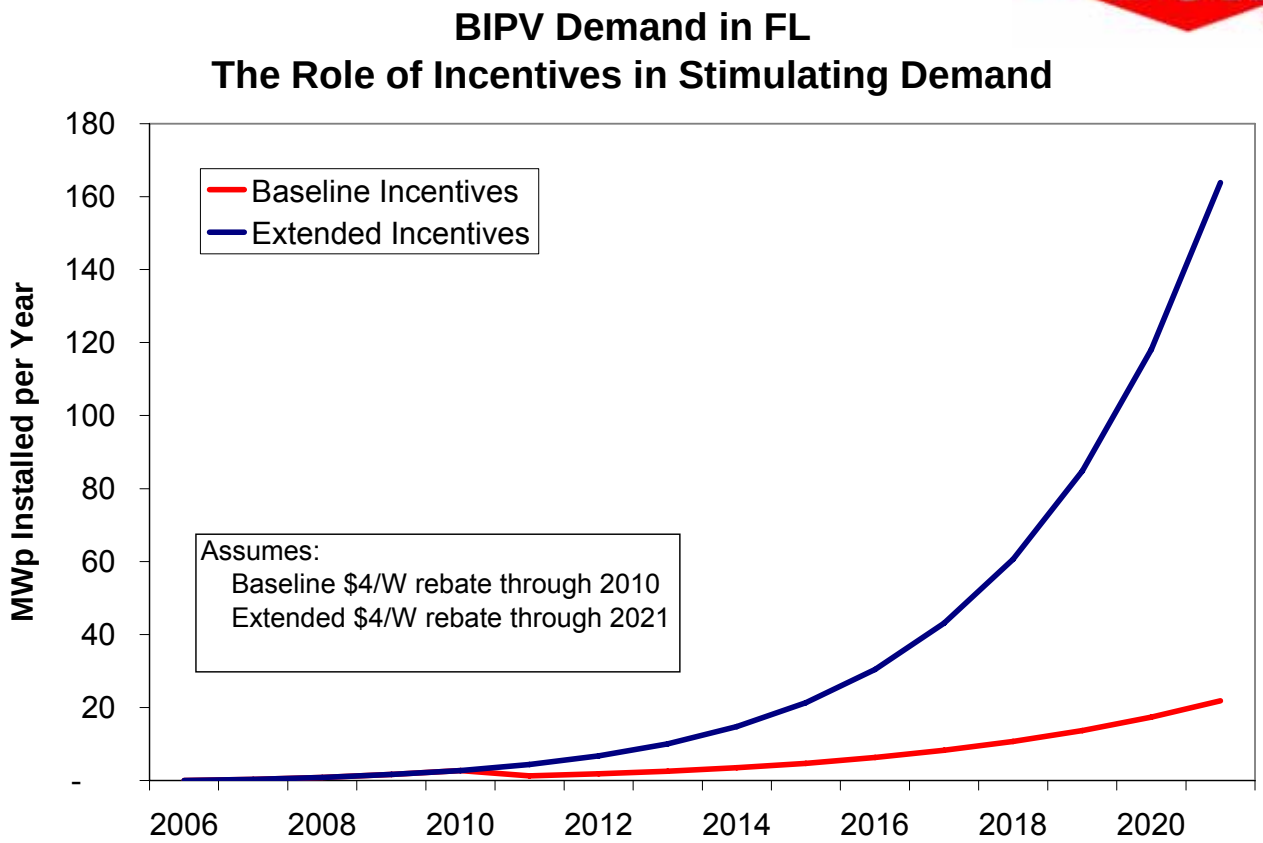
California dominates demand forecasts due to size, head-start, incentives

Technical Adoption Rate - California



Incremental sales grow with increased acceptance and penetration

The Role of Incentives



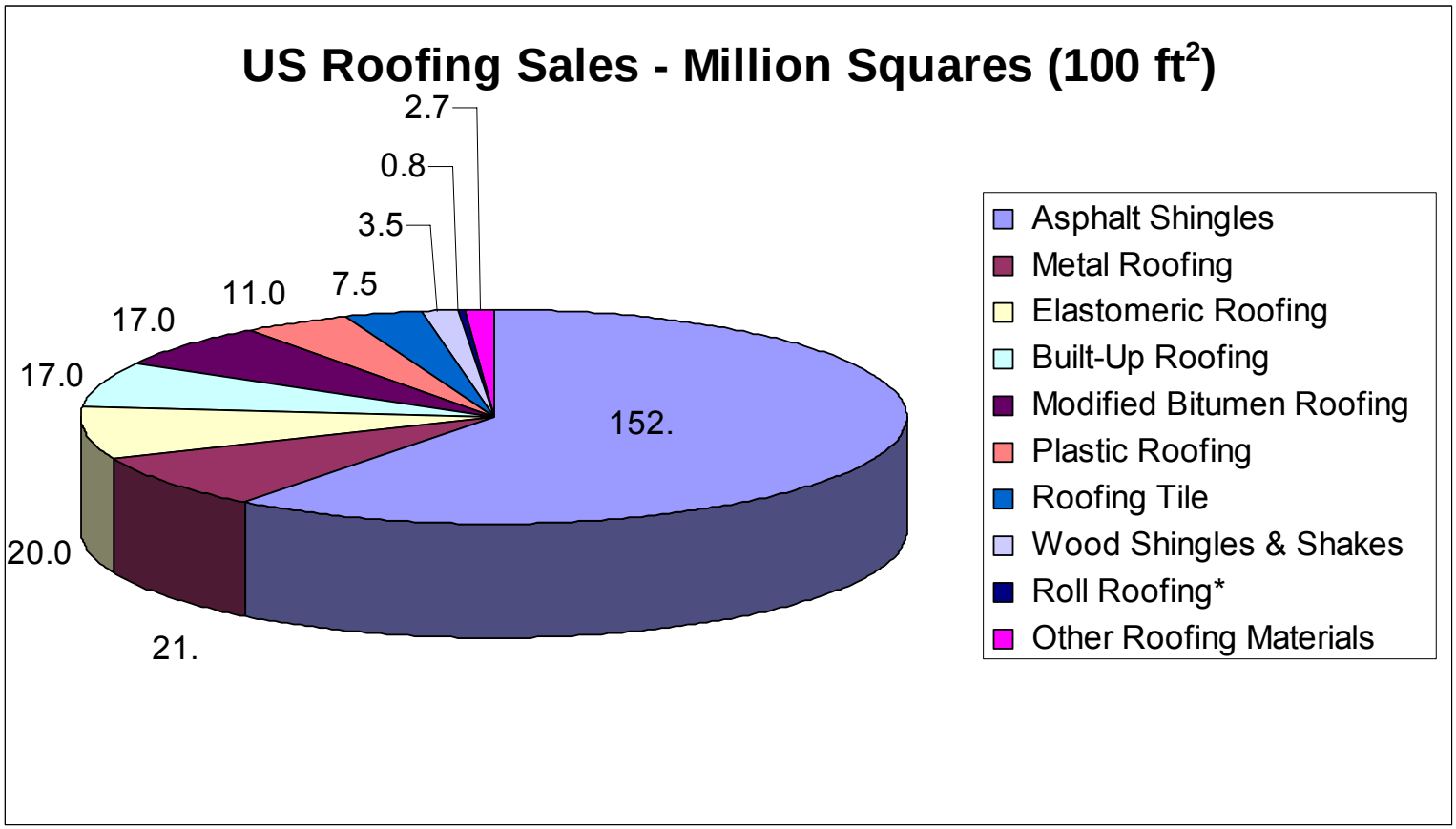
$4/watt rebates stimulate demand

- ✓ Effective installed system costs drop below $2/watt in 2021
- ✓ Acceptance grows to 17% of technical market
- ✓ But, State incentives program costs $650 million/year

Shingle Market

500,000 m2 in 2015 = 54,000 Squares

1 Million Squares Represents 1 G-Watt Annual Installation Opportunity



Conclusions

1. BIPV demand will grow
2. Technical potential is large
3. Early Majority potential is enormous
   - ✓ Virtually all houses can support a 3,300 W kit
   - ✓ 1% of Shingle market equals 1.5 gigawatts
4. Market penetration will follow established patterns
   - ✓ 10 to 20 years to get from 10% to 90% penetration

Project Alignment with Technology Roadmap

IBIS Market Adoption Analysis Conclusion:

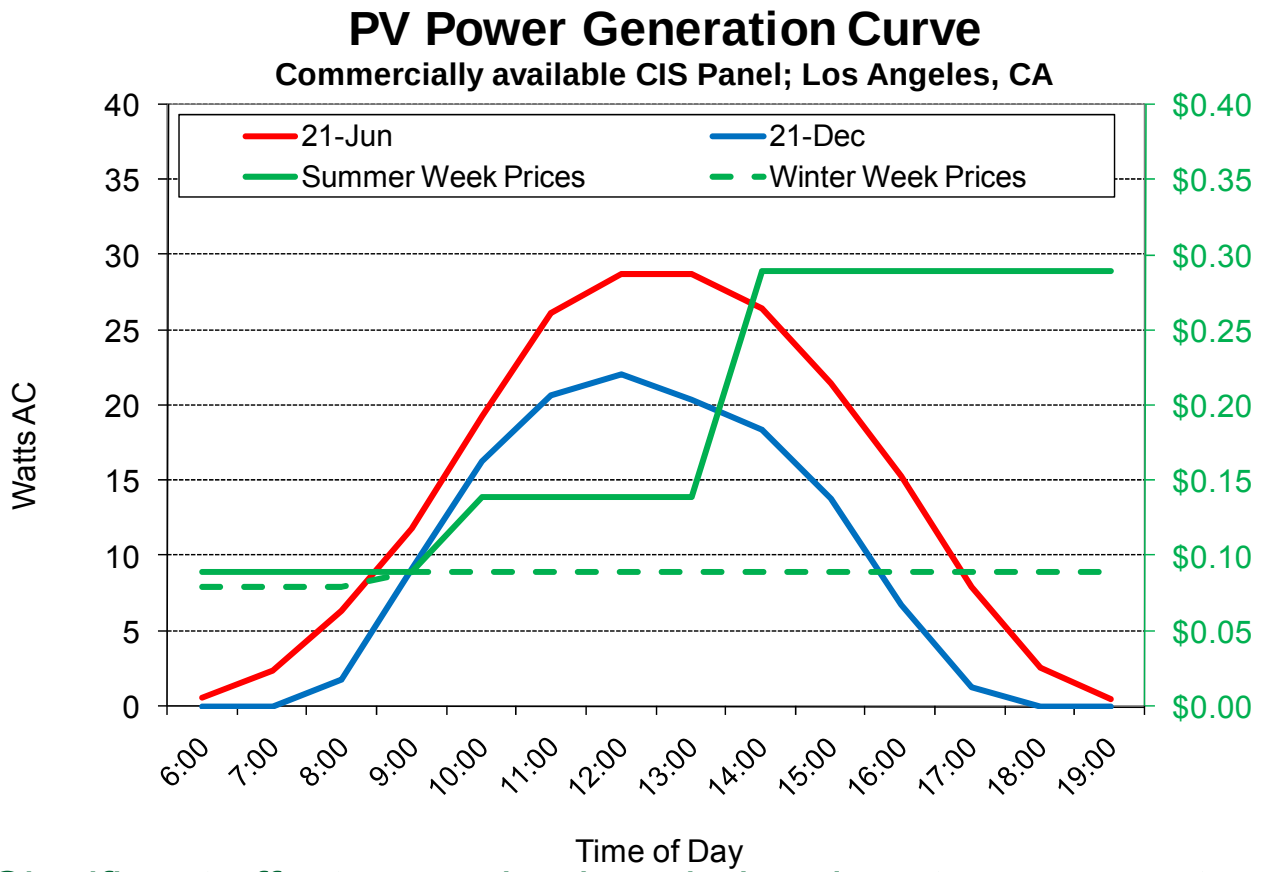
System Cost and Grid Electricity Price have strongest effect on Market Growth

Overarching Goal of Dow Chemical's SAI Project:

Grid Parity!

PV Power Generation

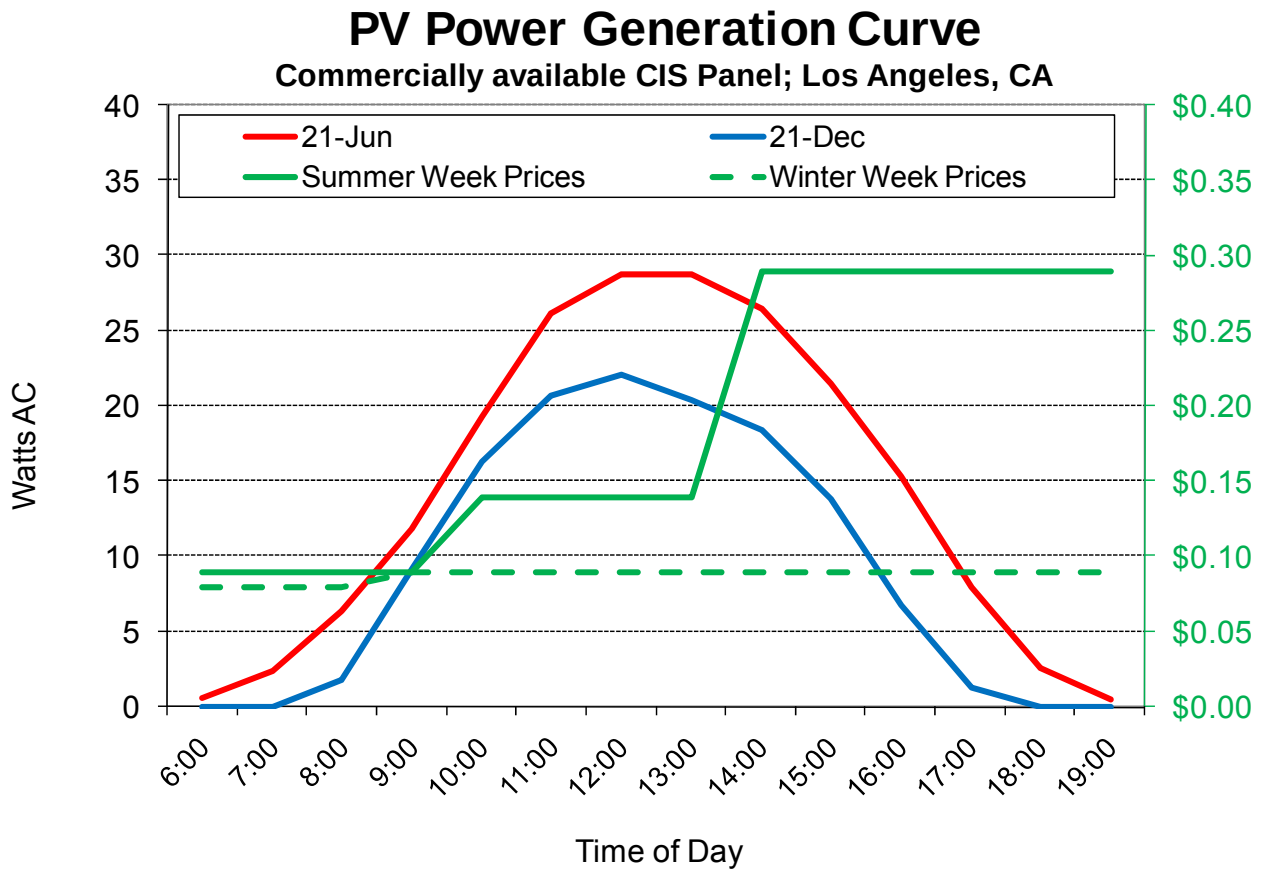
Power generation varies by time of day and time of year, as do grid prices



- ✓ Significant effect on payback period and customer acceptance
- ✓ Advanced metering required to capture PV benefits

Utility Based PV and System Congestion Issues

The Good News - Utility based solar creates power during peak hours



Utility Based PV and System Congestion

The Bad News - Utility based solar creates power during peak hours

Congestion results in an inability to transmit power from a specific point of delivery to a specific point of receipt

- ✓ "High coincidence" results in high transmission costs
- ✓ New transmission infrastructure will be required
  - At least $317,058 per pole (230 kV, steel pole)
    - 60 kV to 115 kV: $69,000 per mile
    - 115 kV to 230 kV: $690,000 per mile
    - 230 kV to 500 kV: $1,100,000 per mile
  - Substation enhancements: approximately $830,000
  - Siting new transmission lines is very difficult
    - Enormous right-of-way costs
    - Concern for negative health and environmental impact

Centralized vs. Distributed PV Systems

Centralized – Utility PV

High system “coincidence” - system “congestion” exacerbated

Distributed – Rooftop PV

Distributed, “rooftop” PV eliminates transmission issues caused by “coincidence” and lack of capacity – equals reduced investment

Distributed PV – The Bottom Line

The Bottom Line –

Traditional Large Scale Renewable Power Generation Systems (Solar PV, Solar Thermal, Wind) all require significant investment in new transmission infrastructure

Distributed PV (roof-top solar) is in place – zero distribution investment penalty

Roof-top Solar has value beyond standard LCOE calculation – 2-4¢/kwh bonus!

SAI TPP Roadmap

1. Reduced “module” cost
2. Reduced installation cost
3. Reduced distribution cost
4. Eliminate transmission infrastructure investment

Project Alignment with Technology Roadmap

Needs	Approach
1. Reduced "module" cost	✓ Reduced PV Cell cost (CIGS on Stainless Steel – Global Solar) ✓ Design for large scale mass production
2. Reduced installation cost	✓ True BIPV Integration ✓ Design for low cost install ✓ Design for high reliability, foolproof, easy diagnostic interconnection
3. Reduced distribution cost	✓ Dow direct channel to market
4. Eliminate transmission infrastructure investment	✓ BIPV – Rooftop installation – power generated where it's used

Planned Work & Accomplishments - Obstacles & Resolution

Obstacle: CIGS SAI Partner, Miasole dropped from Program

Resolution: Global Solar agreed to join program

Obstacle: CIGS supply not available from Miasole

Resolution: Global Solar supplying 10% efficient CIGS cells

Planned Work & Accomplishments - Obstacles & Resolution

Obstacle: Most films evaluated are inadequate for needed protection of CIGS cells

Resolution: Dow internal developments in concert with outside suppliers have identified high potential approaches

Obstacle: Lack of patent waiver has interfered with DOE discussions

Resolution: Awaiting patent waiver

Obstacle Discussion

Barriers encountered or anticipated that may inhibit success of programs

1. CIGS protection is an issue
2. Code Approval for a new multi-functional product time consuming, expensive and idiosyncratic
3. Long Life testing takes a long time – liability concerns

Conclusion – Dow Chemical SAI TPP

1. Excellent progress has been made
2. All indications are we will meet LCOE Targets
3. Distributed rooftop PV is most effective use of PV for electricity generation
4. Challenges remain with respect to form factor options due to limited options on top sheet protection for CIGS
5. Alternative PV options remain and will be evaluated

Conclusion – Dow Chemical SAI TPP

Goal: Large Scale (gigawatt) Cost Effective Distributed Rooftop Electricity Generation

Results: Feasibility is real, products in development, pilot line operational within 12 months

Thank you for your attention

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