William F. Banholzer
Executive Vice President and Chief Technology Officer
March 22, 2011

The Challenge of Taking a New Idea into a Commercial Business

The Story of the Dow POWERHOUSE Solar Shingle

Global Megatrends

HEALTH & NUTRITION

ENERGY

CONSUMERISM

TRANSPORTATION & INFRASTRUCTURE

Why Dow Solar?

Dow chooses to operate where
materials science expertise drives success

Energy Storage

Superior Materials:
Cathode
Anode
Electrolytes
Separator

Water Purification

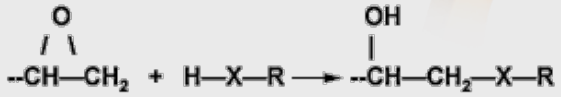
Superior Materials:
Energy efficiency improvements for reverse osmosis and ultra-filtration separations.

Energy Generation

Superior Materials:
Balance Of Systems
Aesthetics
Performance
Durability

Size is a Competitive Advantage

- *Ultra low viscosity*
- *High heat resistance*
- *Hydrocarbon based*



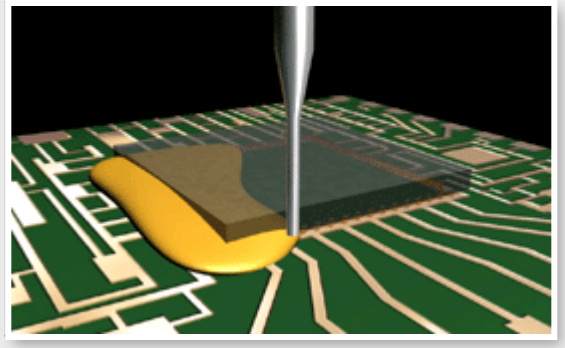
EPOXY 12

Unique Building Blocks

AIRSTONE™ Systems for Wind Energy

Dow Epoxy Systems

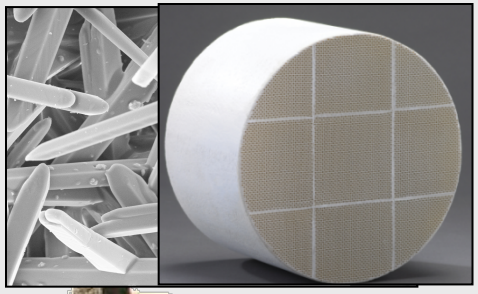
Performance Products

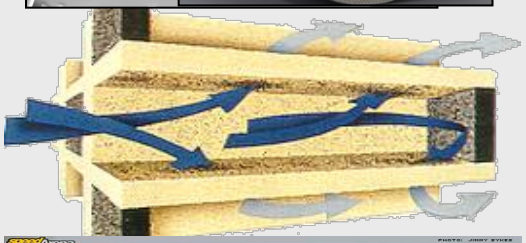


Chip Underfill

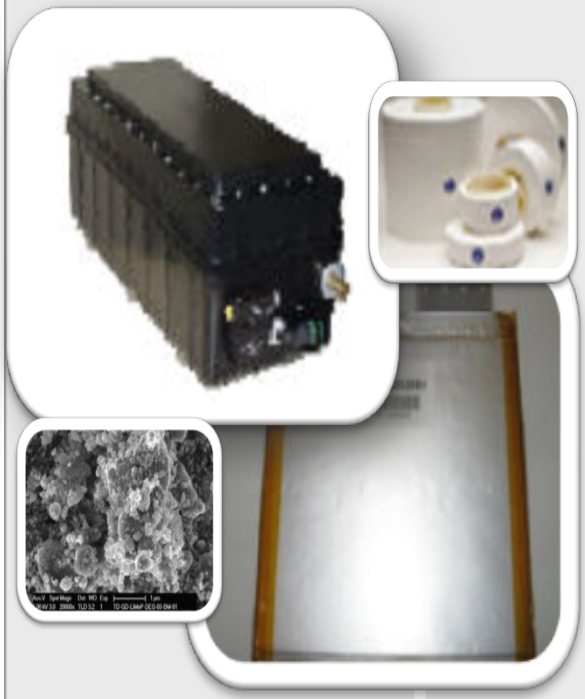
Formulated Products

R&D Interests – Energy and the Environment

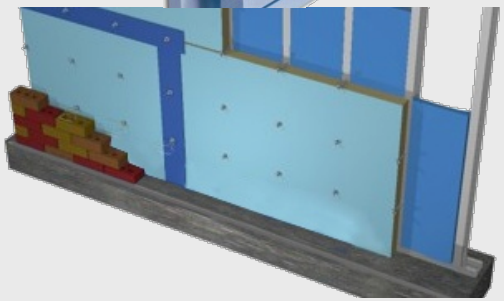




Dow Automotive Systems:
AERIFY™ Diesel Particulate Filters



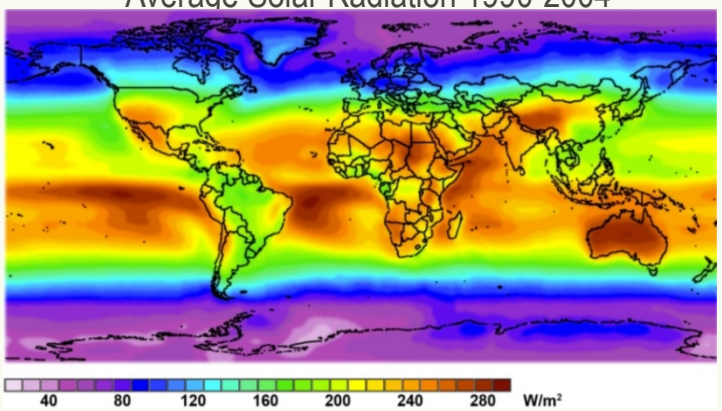
DOW KOKAM



Dow Building & Construction:
Energy Efficient Roof & Wall Solutions

Potential for Solar

Solar Capture Process	W/m²	Efficiency
Sugar Cane to Ethanol	0.60	0.30%
Energy Crop - Fermentation	0.70	0.32%
US Corn to Ethanol (gross)	0.32	0.16%
Algenol	4.0	2.0%
Wind Farm	4.0	2.0%
Concentrated Solar	3.2	1.6%
PV cell (10%)	***20***	***10%***

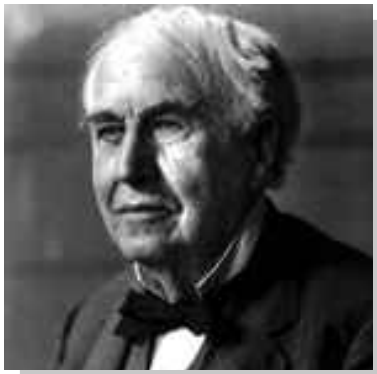


Total solar energy on land
= 697,000 EJ/year

1300 x world needs!

"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 1931



Issues:

- **Intermittency**
- **Cost**

Adapted from Mines ParisTech / Armines ©2006

Dow Participation in Solar

- PEG cutting fluids
- Ethylcellulose paste binder
- Cleaning fluids & slurries
- Light induced plating
- Flexible front sheet materials
- EVA replacements
- Back sheet materials
- Adhesives
- Printed metallization
- Liquid acrylics
- Thermoplastics,
- UV curable liquid encapsulants
- Ion exchange resin
- HTTF for distillation & reduction
- Ultra pure water & waste water treatment
- Polycrystalline silicons
- Monosilane gas for thin films

DOW CORNING

BIPV

- CIGS
- Printed metallization
- TCOs for point contact
- Barrier layers
- CIGs inks
- Epoxies
- Adhesives
- Performance plastics
- XL EVA encapsulant films

BAPV

- High Temperature Thermal Fluids
- Epoxies

CSP

DOW

Dow CSP

Concentrated Solar Power

DOWTHERM™ A
Heat Transfer Fluid

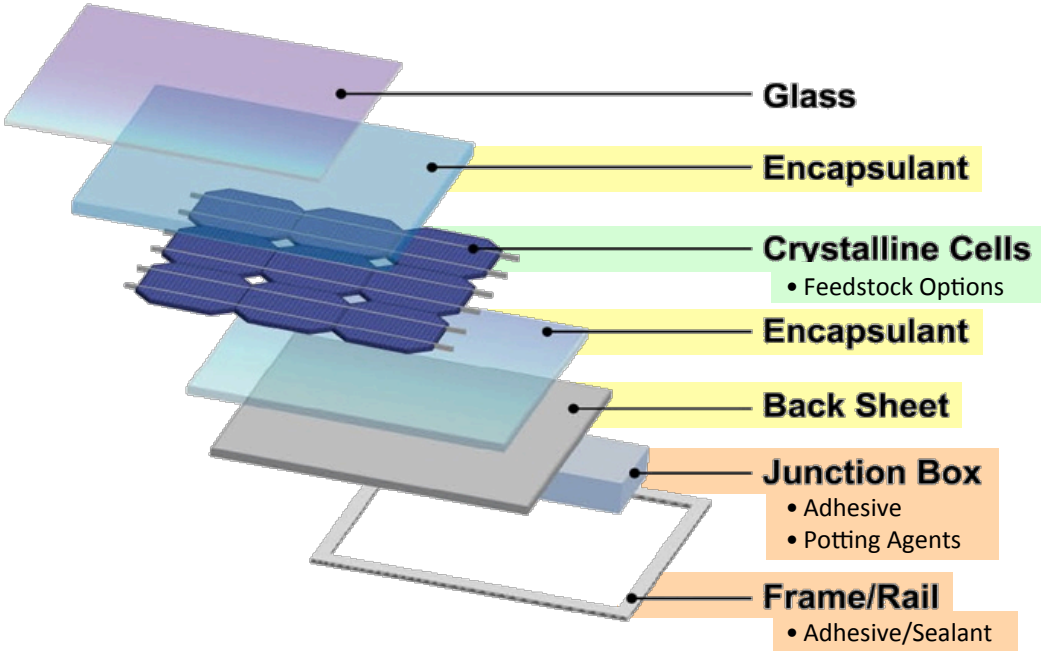
- Established relationships with important system OEMs
- Proven ability to deliver high volumes to remote locations
- Back integration to key raw materials

Addressable Market:
5,000 MW by 2020

Generating 400 MW of power in Spain and North America
Supplying 250,000 homes with electrical power
Reducing carbon emissions by 800,000 MT annually

Silicon Based Cells

Silicon Based Solar



Crystalline Polysilicon Cells

- 6 decades of proven performance
- World class IP
- HSC is leading world supplier

DOW CORNING

$3,200 MM/year market
20% annual growth

Dow PV Encapsulants & Backsheets

- UV resistance
- Electrical resistivity
- Reduced water transmission
- Chemical stability

$500 MM/year market
30% annual growth
$1B by 2011

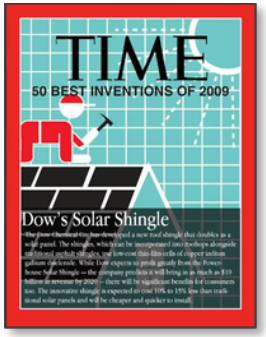
Silicones: Durable & Transparent

- Frame sealing/bonding
- Structural bonding
- Junction box potting agents
- Adhesives
- Encapsulation

DOW CORNING

DOW

Dow BIPV



NEW Addressable Market: ~$5B by 2015 compared to ~$1B for niche PV

Solar – The Same Challenges

PV cells alone do not make a business

SOLYNDRA received:

More than *$1 billion* from venture capital

+

$535 million from DOE

$59 million in revenue

$108 million of costs of goods sold

17.2MW of CIGS panels shipped- ***Bankrupt***

GREENTECH IPOS WITHDRAWN		
Firm	Sector	Date
Daqo New Energy	Solar Poly	IPO withdrawn Jan 2010
Solyndra	CIGS solar panels	IPO withdrawn June 2010
Trony Solar	a-Si solar	IPO withdrawn Aug 2010

http://www.greentechmedia.com
Greentech IPO Report: Past, Present and Top Ten IPO Candidates August 16, 2010
http://seekingalpha.com/article/211350-lessons-from-solyndra-s-failed-ipo
Lessons From Solyndra's failed IPO, Greentech Media

Thin films - a challenging space

Excluding First Solar there are now 170 companies in the sector and more than $2 billion invested over 2 years timeframe.

< 100MW sold in 2008

GLOBAL SOLAR

nanosolar

SOLOPOWER

AQT

UNI-SOLAR
United Solar Ovonic

PowerFilm
Ultra Flexible Solar Modules

www.gtmresearch.com/report/thin-film-2010-market-outlook-to-2015
www.renewableenergyworld.com/rea/blog/post/2010/05/whats-coming-for-solar-thin-film
http://www.nrel.gov/analysis/pdfs/46025.pdf

W Banholzer 2012 Reilly Lecture Notre Dame

Major Obstacles to Residential BIPV Adoption

Cost

<u>SunPower</u>

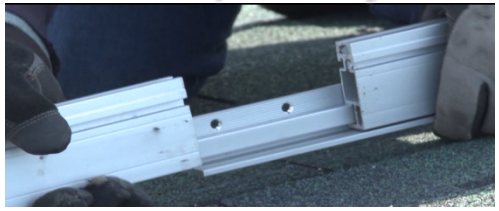
- Cost = $7.50-9.00/Watt installed
- Requires premium s-tiles/concrete roofing tiles

<u>Atlantis SunSlate</u>

- Cost = $13-$15/Watt
- Requires premium roofing slates
- Heavy (Si panels + fiber cement slate)
- Labor intensive

Roof Integrity/Warranty

Installation Complexity



Aesthetics

Head to Head Competition

The Challenges of Supply

Channel Selection

Builder Direct,
Building Material Distributor,
Solar Integrator

Markets Selection

Reroofing, Retrofit, Commercial,
Residential, New Construction

Example: **Solar Integrator / Residential New Construction**

DOW SOLAR → Solar Integrator → Custom Bldr /Re-roofer → Home Owner

Sell Products	Design Arrays	Custom Kit Creation	Site Assessments	Permitting	Utility Interconnect	Tech. Sales	Installation

Requires: New Supply Chain (Packaging, Order Logistics)
Define Sales Location, Product Claims, Warranty, Product Awareness, Regional Codes & Standards, Installation Guides, Inverter Selection, Training, Data Monitoring Selection, etc….

Codes and Standards

Thousands of In-house and Agency Tests
300,000 Man Hours Of Engineering
Building, Safety, and Performance Codes

MIAMI DAMP HEAT

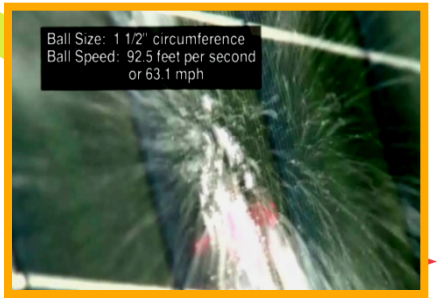
MIDLAND SNOW & ICE

PHOENIX DRY HEAT

UL790 TEST
CLASS A BEST RATING

HANDLING & INSTALLATION

HAIL & INCLEMENT WEATHER



0443 (PV)
TAS 100-95
ASTM D635
IEC 61646

UL 790
UL1897
ASTM E1929
ASTM DS2843

0445 Plastics
UL 746
UL 514
UL 1703
ASTM DS2843

Success…….

Or Failure?

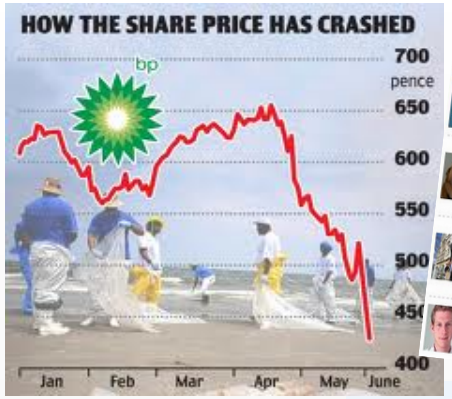
20 year life product

Generates profit

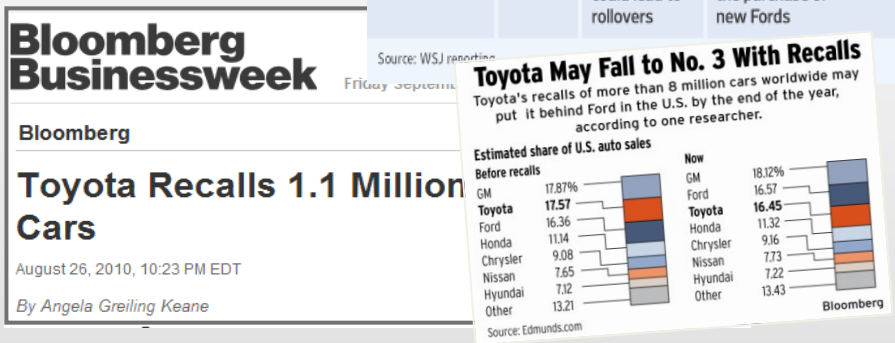
Excellent roofing properties

Excellent electricity generation

Strong consumer demand



http://econotwist.wordpress.com/2010/07/06/bp-rules-out-issuing-new-shares/



Reliability is not optional

First Solar Q4 Financials, 2012 Guidance: Challenges Ahead

In order to thrive, First Solar must deploy 65 GW of photovoltaic panels over the next decade.

First Solar is addressing a product which will cost hundreds of millions beyond its product warranty. The CEO, Mike Ahearn, referred to the product failure as a manufacturing excursion.

Panchabuta-Renewable Energy & Cleantech in India

Home About Archives

NEWS,ANALYSIS AND INSIGHTS IN RENEWABLE ENERGY AND CLEANTECH INDUSTRY IN INDIA

ABOUT CLEANTECH/RE WIND SOLAR BIOMASS SMART GRID CLEANFUEL FINANCE OTHER CDM GREEN BUILDING

OTHER, SOLAR

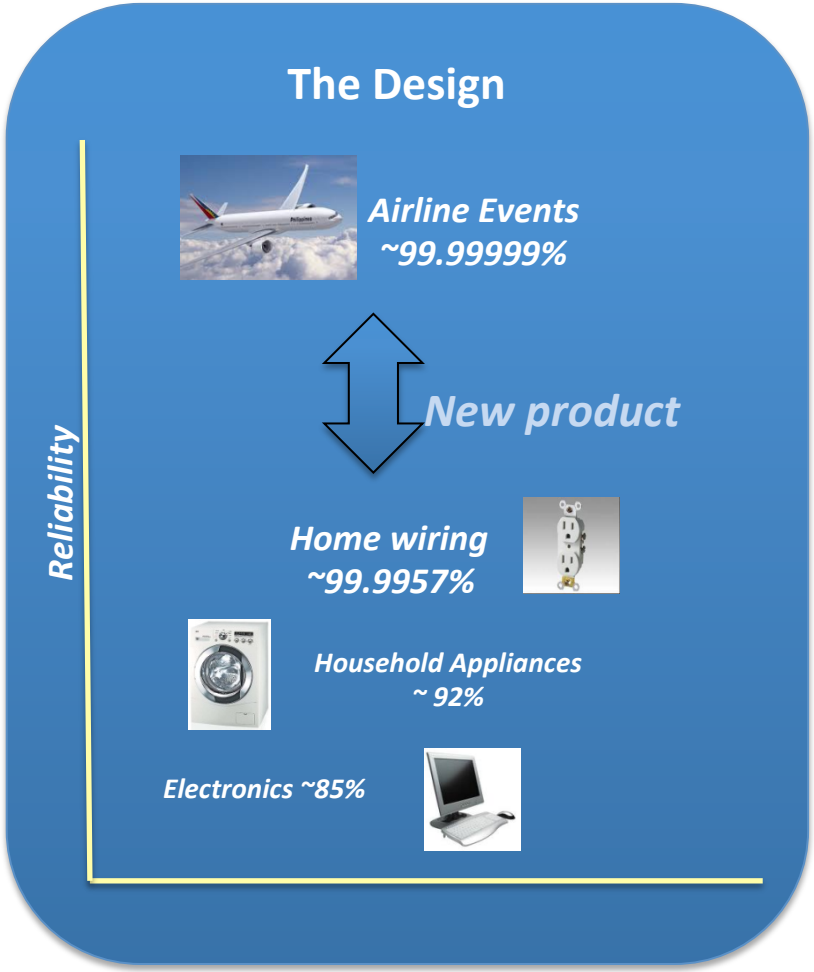
First Solar admits to increased failure rates in hot climates like India

POSTED BY PANCHABHUTHA - MARCH 6, 2012 - LEAVE A COMMENT

FILED UNDER FIRST SOLAR

W Banholzer 2012 Reilly Lecture Notre Dame

Reliability Targets



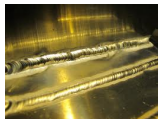
Key question:
Where do you position New Product?
Balance cost and reliability

Has the reliability target been established?

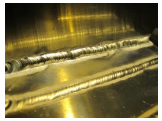
And does the test protocol validate the target?

Reliability Targets

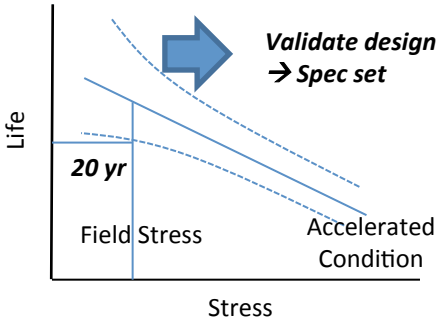
Reliability Target	Design Capability	Process Capability	Production
20 yrs on the roof	Is design capable of 20 yr life?	Does process meet design requirements?	Are process & design intent met in every part?



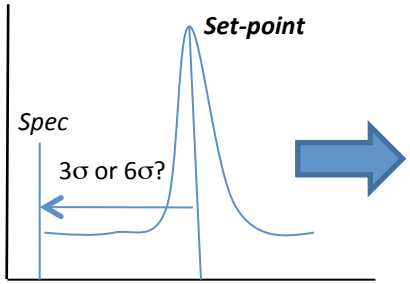
Weld joint
- **System 1E-3**
- **Each joint 1E-4 (2 welds/joint)**



Weld joint
- **Individual weld 1E-2 or 3.8 σ**



Prototype parts - small "n"



Production parts - large "n"

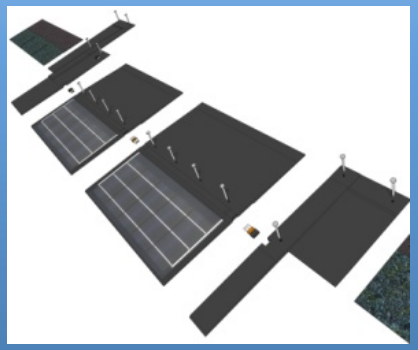
Control plan to assure capability is maintained

Concept to Commercialization Expensive

Systems Approach

The Product

1 Shingle



1 String

10's of Shingles

1 Inverter

100's of components

1 Grid tied array

10's End pieces

100's Power electronics

100's of Shingles

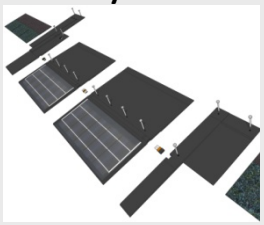
Establish performance & reliability targets based on system look

Reliable Process and Product Design

System

1 Grid tied array

Sub-system



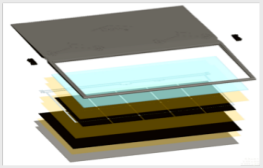
1 Inverter

10's End pieces

100's Power electronics

100's of Shingles

Component

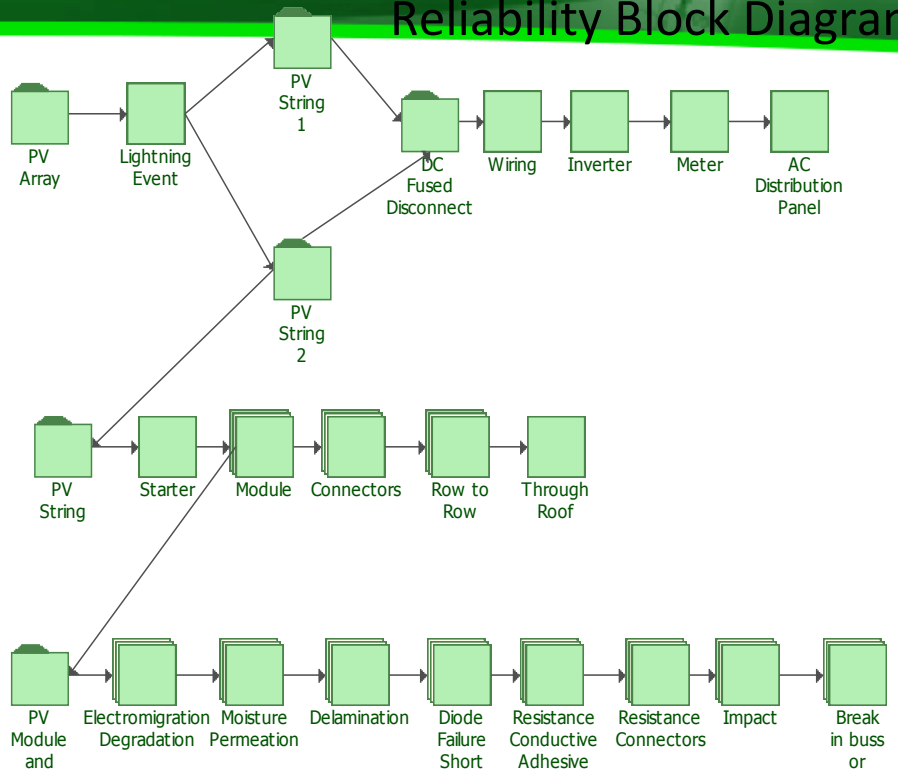


100's of connections

1000's welds

1000's of discrete pieces

Reliability Block Diagram

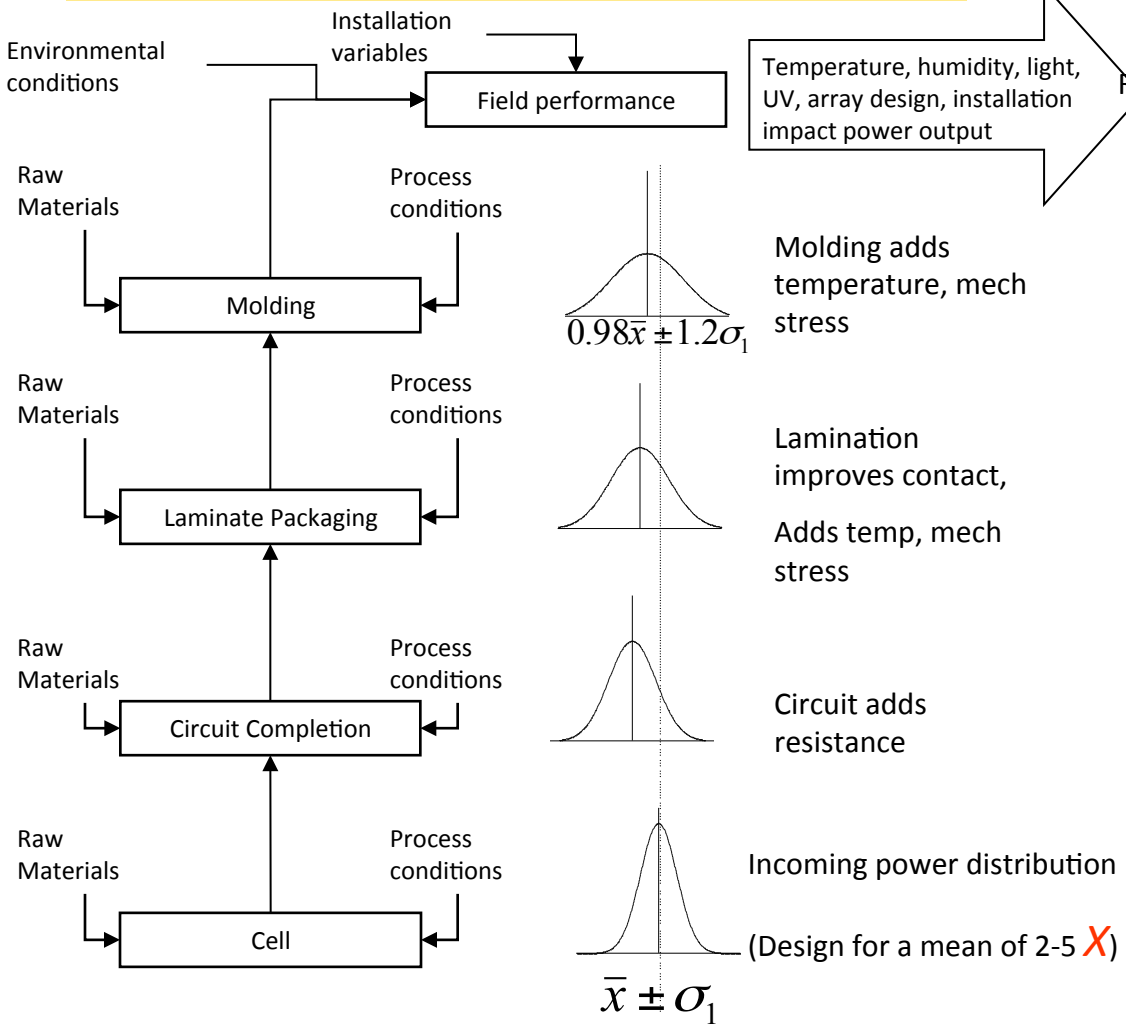


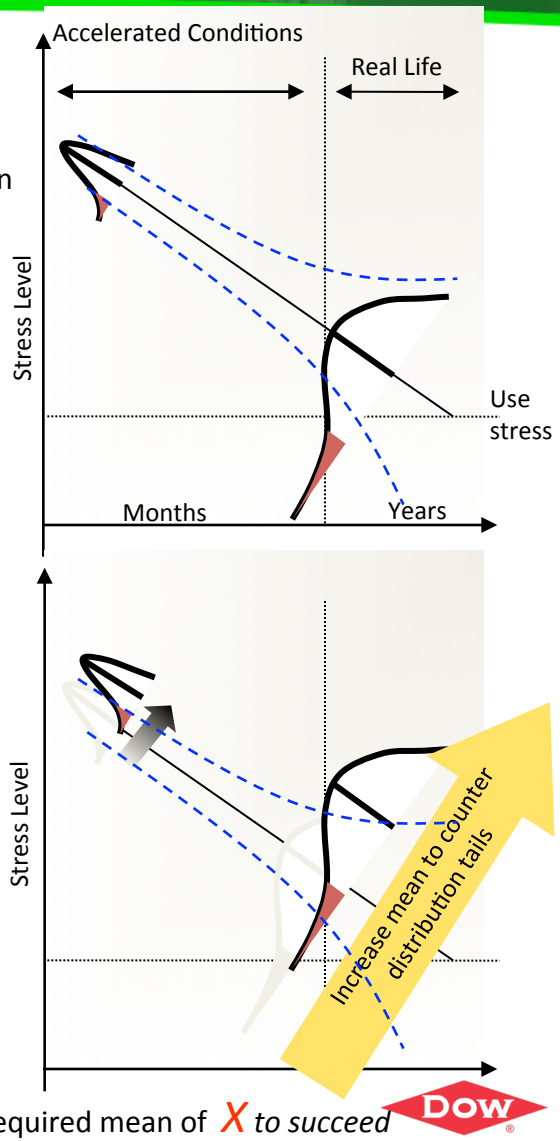
System Reliability = Component Reliability **x** Sub-system Reliability

Robust Design for noise variables like environment and installation

Reliable Process and Product Design

Cost effective design requires statistical tolerance
Worst case stack up is impractical



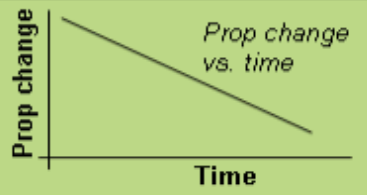


Calculating Acceleration Factors

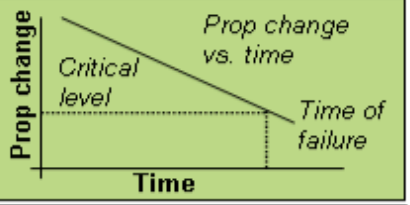
1. Determine stress levels → for ex. 3-5 levels of temperature

   → ▪Temp range → 65-125 C
   ▪Temp interval → 15 C

2. Calculate property change vs. time at each stress level

   → 

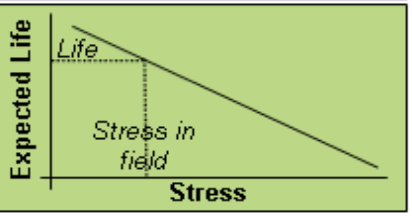
3. Determine failure point at each stress level & calculate time to failure at each stress level

   → 

4. Determine equivalent field stress for representative time period → for ex 1 yr

   → ▪Sum degradation using field data
   ▪Calculate equivalent exposure stress

5. Estimate time to failure at equivalent field stress based on step 4

   → 

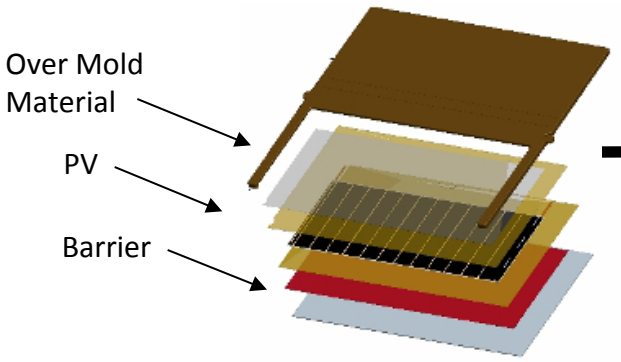
Challenges of Material Design and Selection

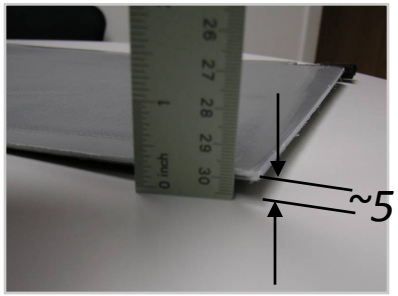
Materials Challenges

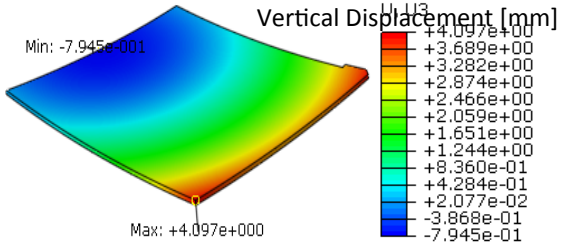
- Over 20 Materials With Different Material Properties
- Over 40 Interfaces Of Materials
- Over 15 Assembly Steps

Material Properties & Design

Modulus, CTE, Density, Elastic/Plastic Properties,
Fatigue, Aging Properties,
Interface Properties…etc
Temperature, Stress, Strain, design…







Temp. profile: 85 °C → 23 °C

Calculated : 4.89 mm

Understanding design-material interaction

Minimizing Warpage Through FEA

$$\frac{\partial T_{ij}}{\partial x_j} = \frac{\partial T_{ij}}{\partial X_k}\frac{\partial X_k}{\partial x_j} = 0$$ *Equilibrium*

$$E_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial X_j} + \frac{\partial u_j}{\partial X_i} + \frac{\partial u_k}{\partial X_i}\frac{\partial u_k}{\partial X_j}\right)$$ *Strain*

$$u_i = x_i - X_i$$ *Displacement*

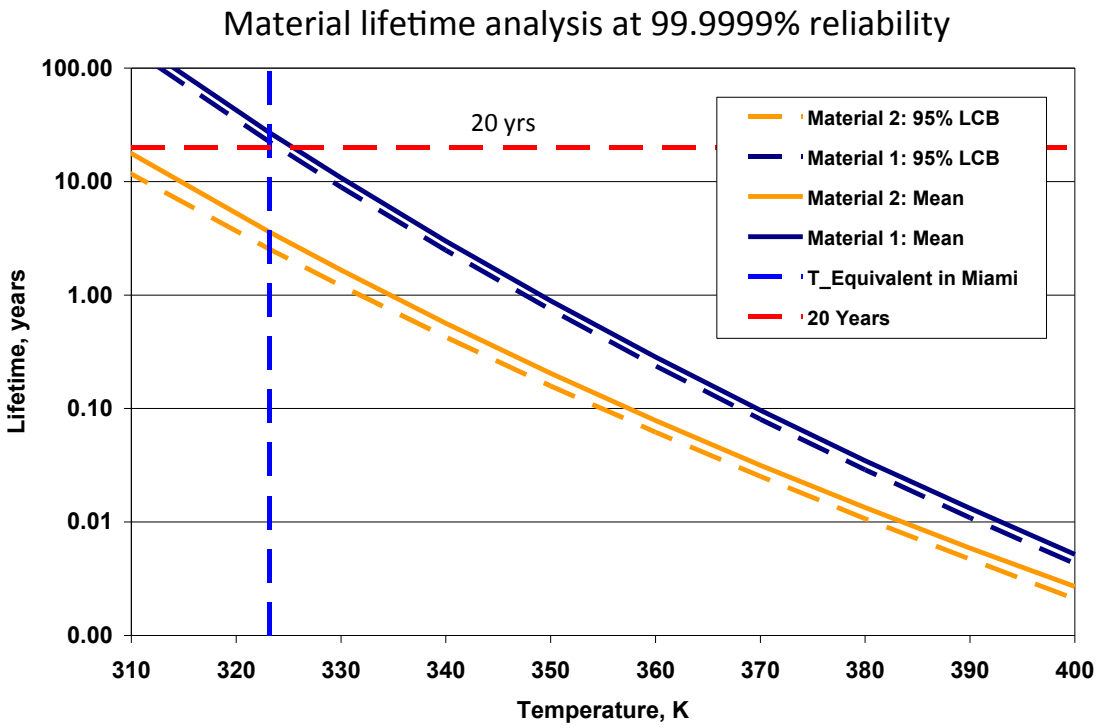
Energy (work) Balance On Multiple Layers

$$\int_S t_i \delta u_i dS + \int_V f_i \delta u_i dV = \int_V T_{ij}\delta E_{ij} dV$$

Traction Force

Body Force

Hydrostable Material Selection



- Tests conducted under multiple accelerated conditions of temperature and humidity
- Failure defined as 50% property change
- Acceleration factor calculated based on the time to failure at each stress condition
- Performance of material 1 inadequate
- Confidence bounds at real stress wide → Handled for material 2 by shifting the mean

Component level testing used successfully
to mitigate material degradation risk in product

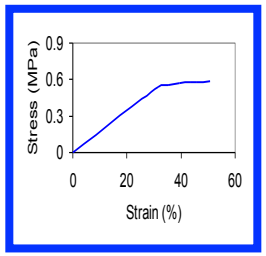
Stress Reduction at the Interfaces

High Modulus Edge	Interface	High Modulus Frame

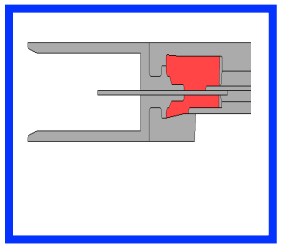
Quantify and minimize strain at interface

Options

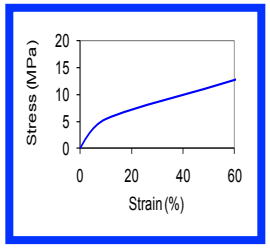
Material A



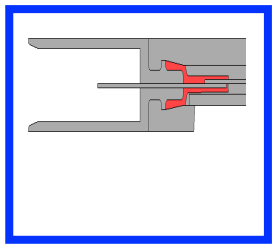
Design 2



Material B



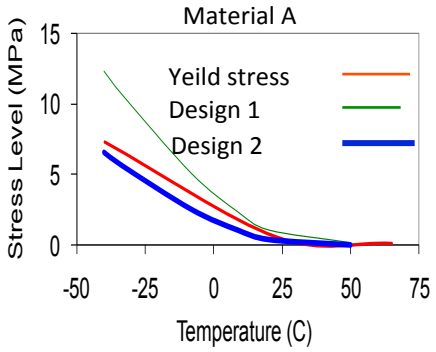
Design 1

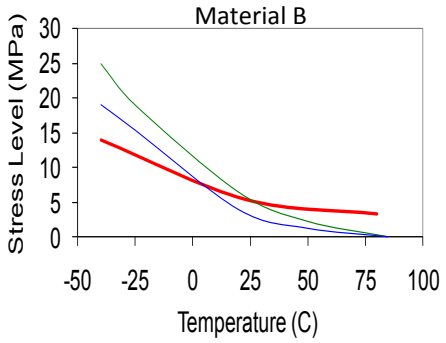


Materials

Designs

FEA





Results

	Design I	Design II
Matl A	✗	✓
Matl B	✗	✗

Explore design-material space to reduce stress at critical interface

The Challenges in Building a Plant

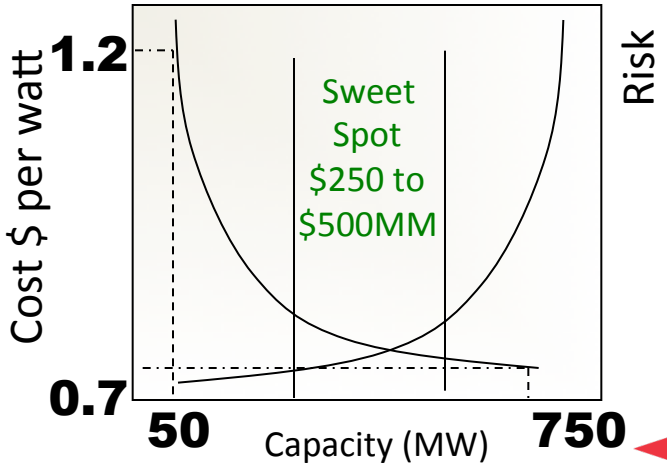
Major Considerations

- Clear Business Case and Alignment
- Project Staffing
- Site Selection
- Permitting
- Front End Loading
- Subject Matter Expert Input
- Risk Assessment & Mitigation Planning
- IPA Project Reviews
- Estimating and Schedule Management
- Construction Safety Management
- Start Up Budget and Staffing Plan

Determine Size and Risk

- Larger capacity of first plant means:
  - Low module cost -Lower flexibility
  - Standardization -Higher capital
    -Higher risk
    -Higher base cost

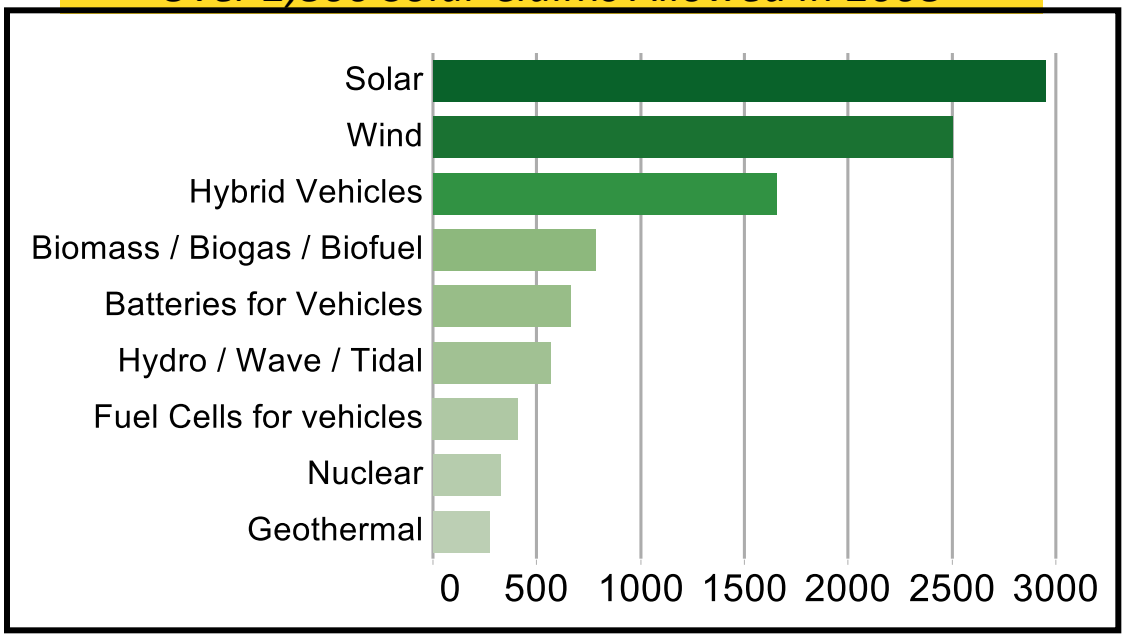
IPA Project Review



W Banholzer 2012 Reilly Lecture Notre Dame

Intellectual Property Strategy – A Must

Over 2,800 Solar Claims Allowed In 2008



No FTO
No IP Strategy

$$$

License Fee
Law Suits
Lost Revenue
Lost Capital

For a <u>single product</u>, Freedom to Operate and IP Requirements include:

30-40 patents
5 man years or more of effort
$650MM in filing and Freedom to Operate
$10MM in Maintenance Fees over 20 Years

What Else Can Go Wrong?

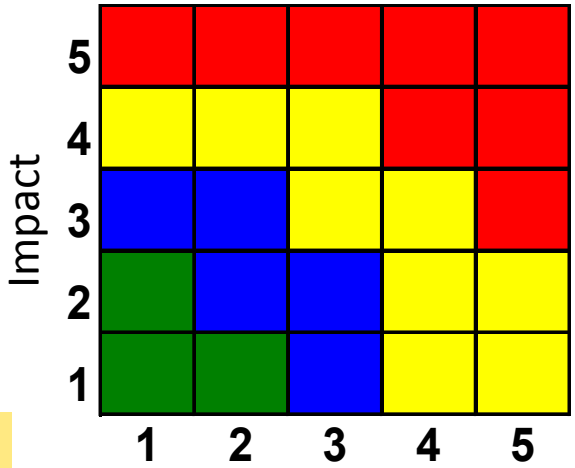
Unplanned Events

Economy Changes
Codes Change
Incentives change
Raw Material Supply

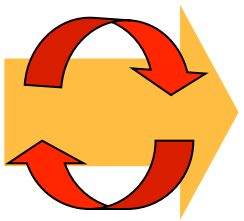
Failure Mode / Cause	Risk Level	Action
Key raw material shortage		Qualify additional sources with equivalent quality
Voids & Inclusions in overmold		Develop Control test or alarm system
Dramatic building code change		Redesign product to be code compliant

FMEA
Failure Modes & Effect Analysis

Risk Assessment



- Redesign
- Retool
- Rationalize



Launch?

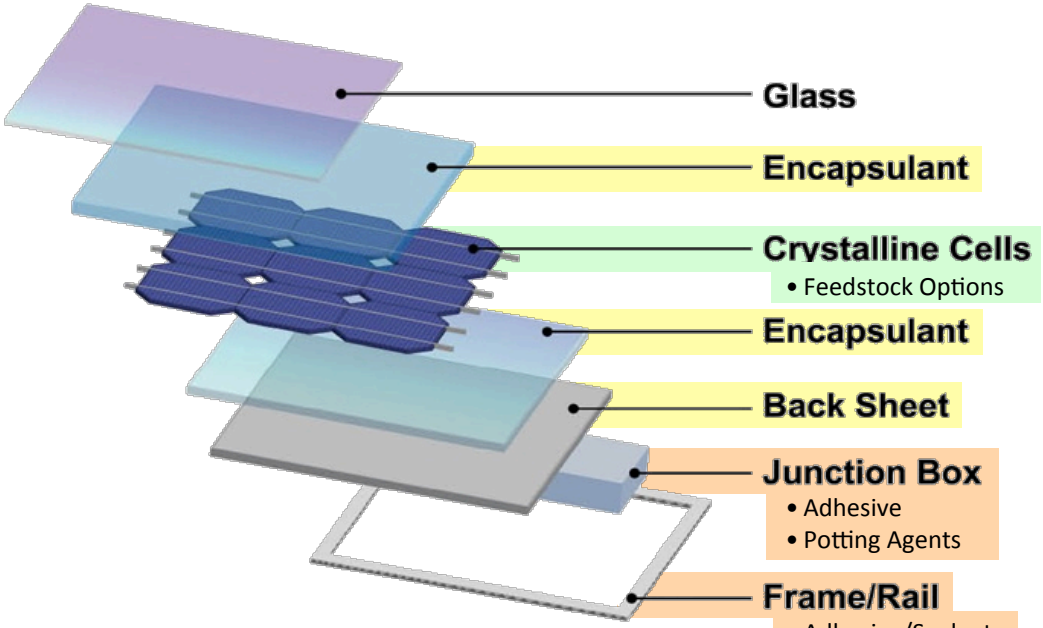
- Verify
- De-Risk
- Certify

0 months *3 months* 6 months


Thank You

Alternative Sources

Silicon Based Solar



Crystalline Polysilicon Cells

- 6 decades of proven performance
- World class IP
- HSC is leading world supplier

DOW CORNING

$3,200 MM/year market
20% annual growth

Dow PV Encapsulants & Backsheets

- UV resistance
- Electrical resistivity
- Reduced water transmission
- Chemical stability

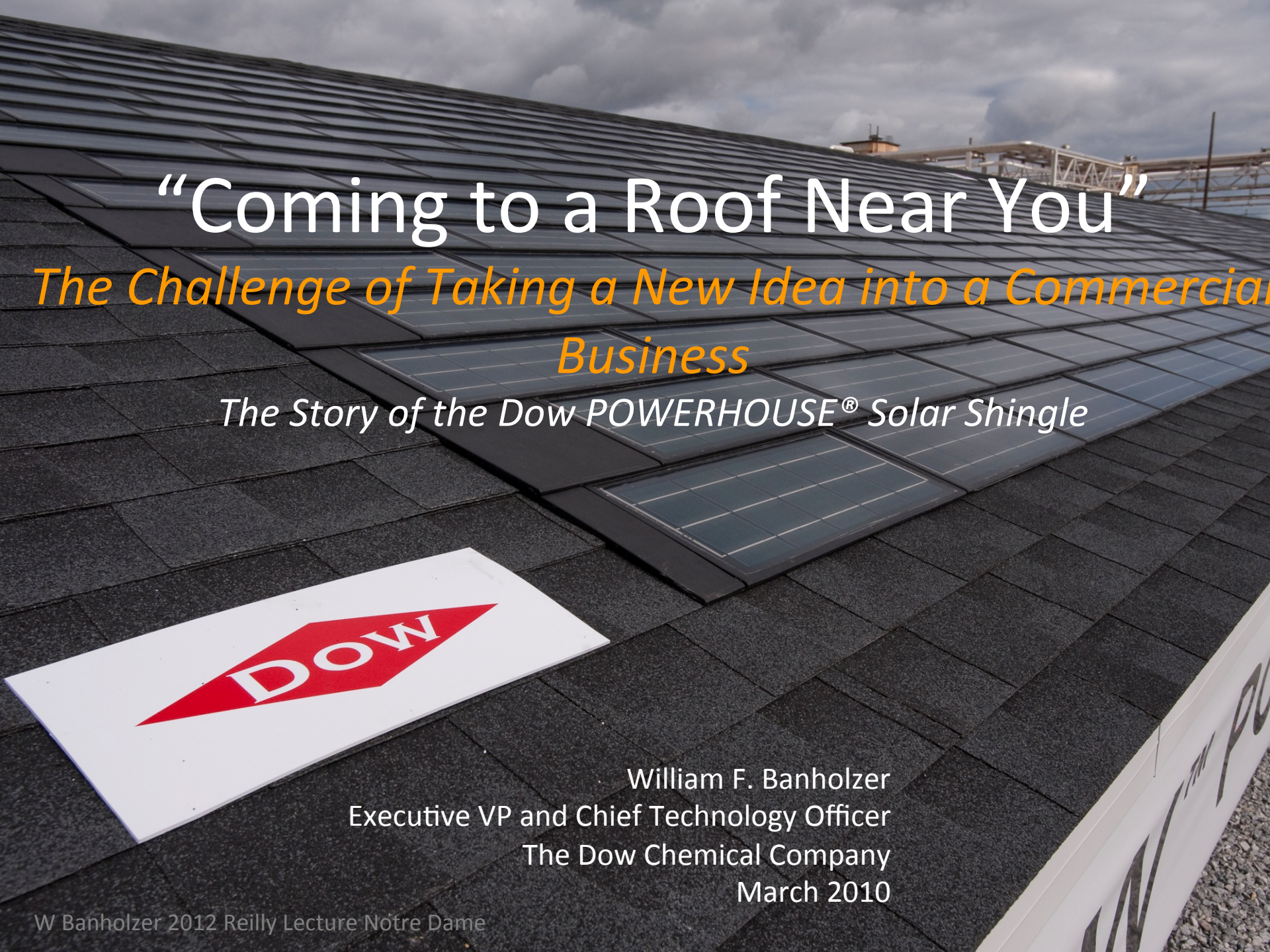
$500 MM/year market
30% annual growth
$1B by 2011

Silicones: Durable & Transparent

- Frame sealing/bonding
- Structural bonding
- Junction box potting agents
- Adhesives
- Encapsulation

DOW CORNING

DOW



"Coming to a Roof Near You"

The Challenge of Taking a New Idea into a Commercial Business

The Story of the Dow POWERHOUSE® Solar Shingle

William F. Banholzer
Executive VP and Chief Technology Officer
The Dow Chemical Company
March 2010

Abstract

The creation of a financially successful product or process from an inventive idea is quite complex. In this talk, the challenge of managing Dow's $1.7 billion R&D budget, including project selection, risk management, and portfolio optimization, will be addressed. The DOW POWERHOUSE™ Solar Shingle (http://www.dowsolar.com/) is a case study that illustrates the multitude of decisions required to commercialize a new energy product. Managing the technical, market and supply chain risks and working with government and industry programs and codes are among the topics that will be discussed.

Deciding What to Work On

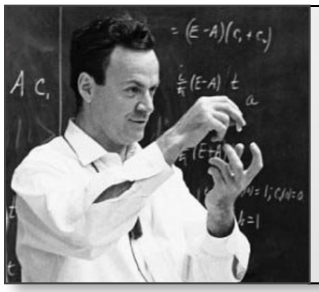
What is the material & energy balance?

What is the cost? Is it sustainable?

Have we defined proper control volumes?

What are the TECHNICAL risks? MARKET risks?

- ***Once you decide on a pathway –***
- ***failure is NOT an option!***



For a successful technology, reality must take precedence over public relations, for Nature cannot be fooled.

- Richard Feynman