The Challenge of Taking a New Idea into a Commercial Business

The Story of the Dow POWERHOUSE Solar Shingle

William F. Banholzer
Executive Vice President and Chief Technology Officer
March 25, 2011

Global Megatrends

HEALTH & NUTRITION

ENERGY

CONSUMERISM

TRANSPORTATION & INFRASTRUCTURE

Deciding What to Work On

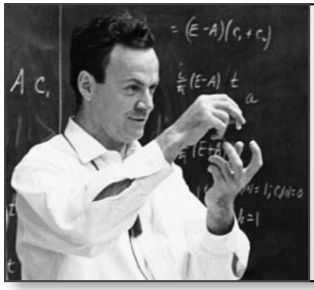
What is the material & energy balance?

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***

Why Dow Solar?

Dow chooses to operate where
materials science expertise drives success

Energy Storage

Superior Materials:
Cathode
Anode
Electrolytes
Separator

Water Purification

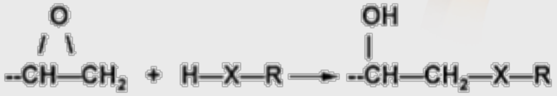
Superior Materials:
Energy efficiency improvements for reverse osmosis and ultra-filtration separations.

Energy Generation

Superior Materials:
Balance Of Systems
Aesthetics
Performance
Durability

Size is a Competitive Advantage

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



$$-\overset{O}{\widehat{CH-CH_2}} + H-X-R \rightarrow -\overset{OH}{\overset{|}{CH}}-CH_2-X-R$$

EPOXY 12

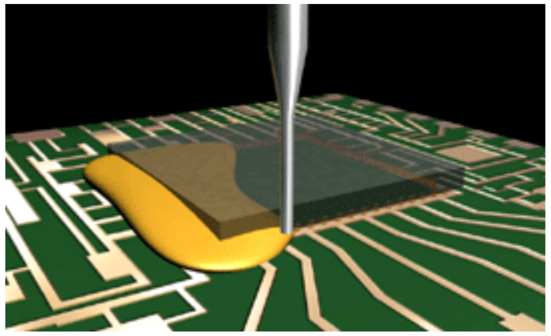
Unique Building Blocks

AIRSTONE™

Systems for Wind Energy

Dow Epoxy Systems

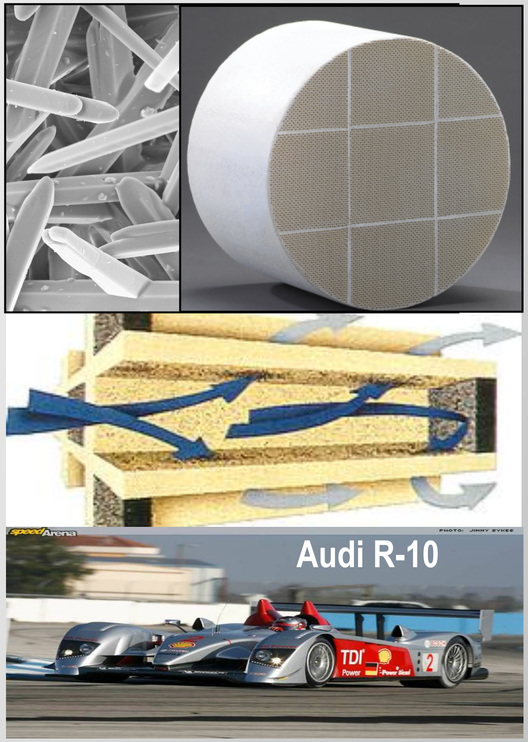
Performance Products



Chip Underfill

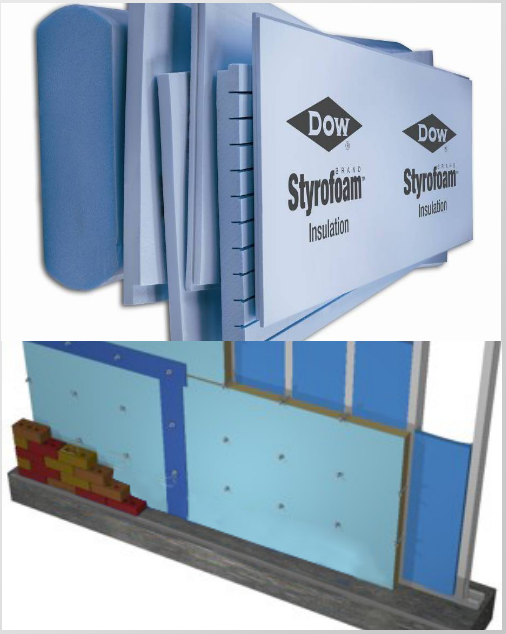
Formulated Products

R&D Interests – Energy and the Environment



**Dow Automotive Systems:
AERIFY™ Diesel Particulate Filters**

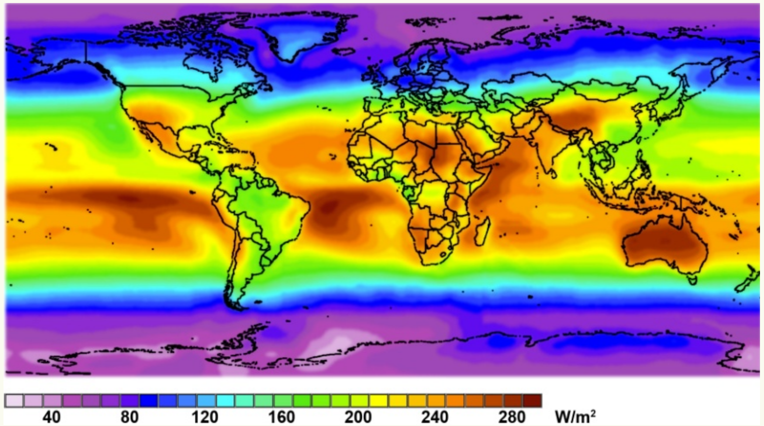
DOW KOKAM



**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%***

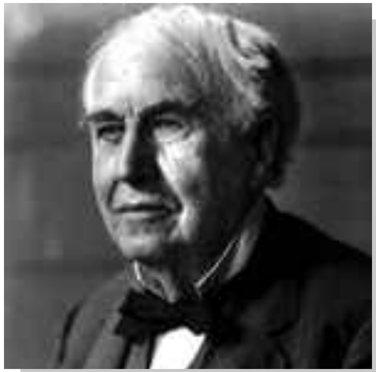


Total solar energy on land
= 697,000 EJ/year

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*

Adapted from Mines ParisTech / Armines ©2006



Issues:

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

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

BAPV

BIPV

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

- High Temperature Thermal Fluids
- Epoxies

CSP

Dow CSP

Concentrated Solar Power

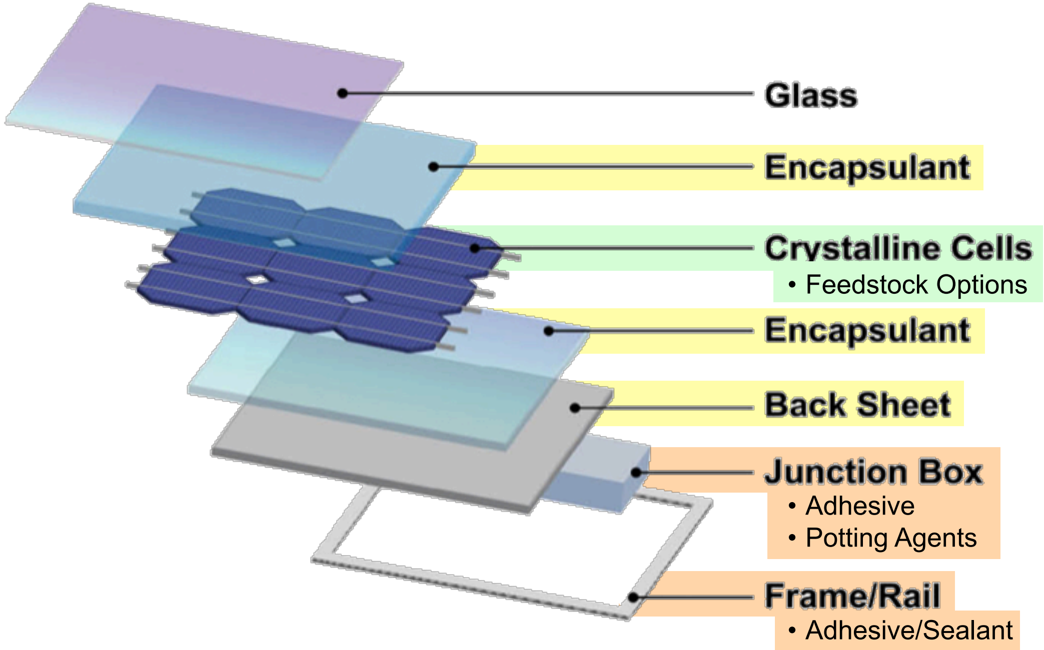
DOWTHERM™ A
Heat Transfer Fluid

- 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 Solar



Crystalline Polysilicon Cells

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

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

Dow PV Encapsulants & Backsheets

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

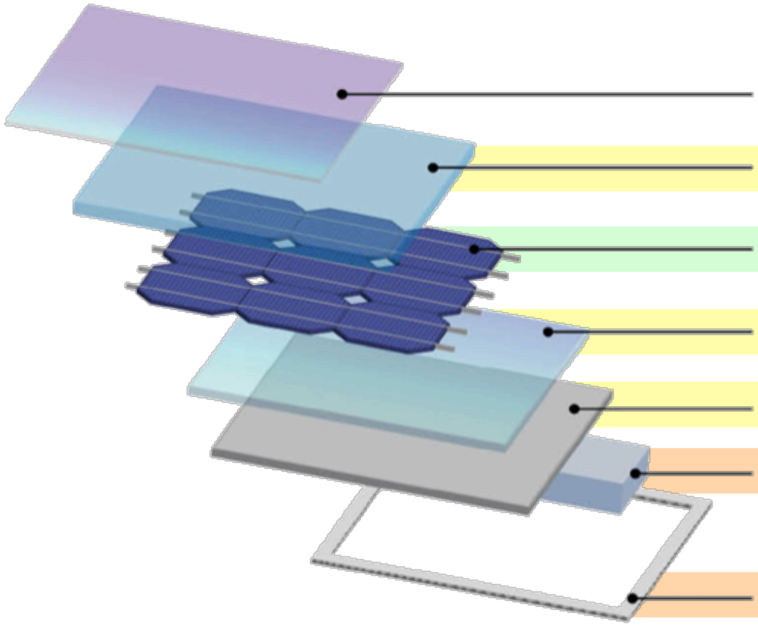
$500 MM/year market
30% annual growth
$1B by 2011

Silicones: Durable & Transparent

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

Alternative Sources

Silicon Based Solar



Glass

Encapsulant

Crystalline Cells
- Feedstock Options

Encapsulant

Back Sheet

Junction Box
- Adhesive
- Potting Agents

Frame/Rail
- Adhesive/Sealant

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DOW CORNING

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DOW CORNING

Dow BIPV

TIME

50 BEST INVENTIONS OF 2009

Dow's Solar Shingle

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

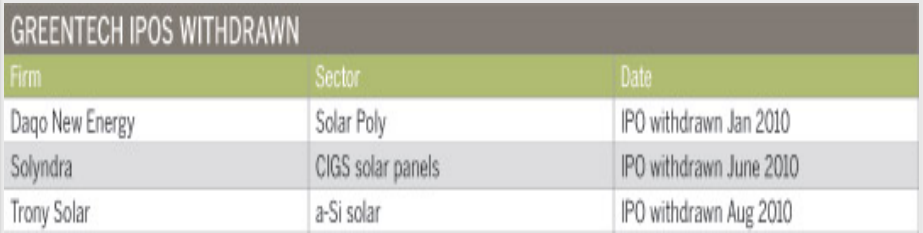
ERIC WESOFF: JUNE 18, 2010

Solyndra IPO Canceled

And they raise another $175 million dollars to bring their VC funding totals to more than $1 billion

Solyndra just announced that it has **submitted a request with the SEC to withdraw its Registration Statement on Form S-1**. The company has decided not to proceed with an IPO of shares of its common stock at this time

$59 million in revenue
$108 million of costs of goods sold
17.2MW of CIGS panels shipped



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

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Major Obstacles to Residential BIPV Adoption

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

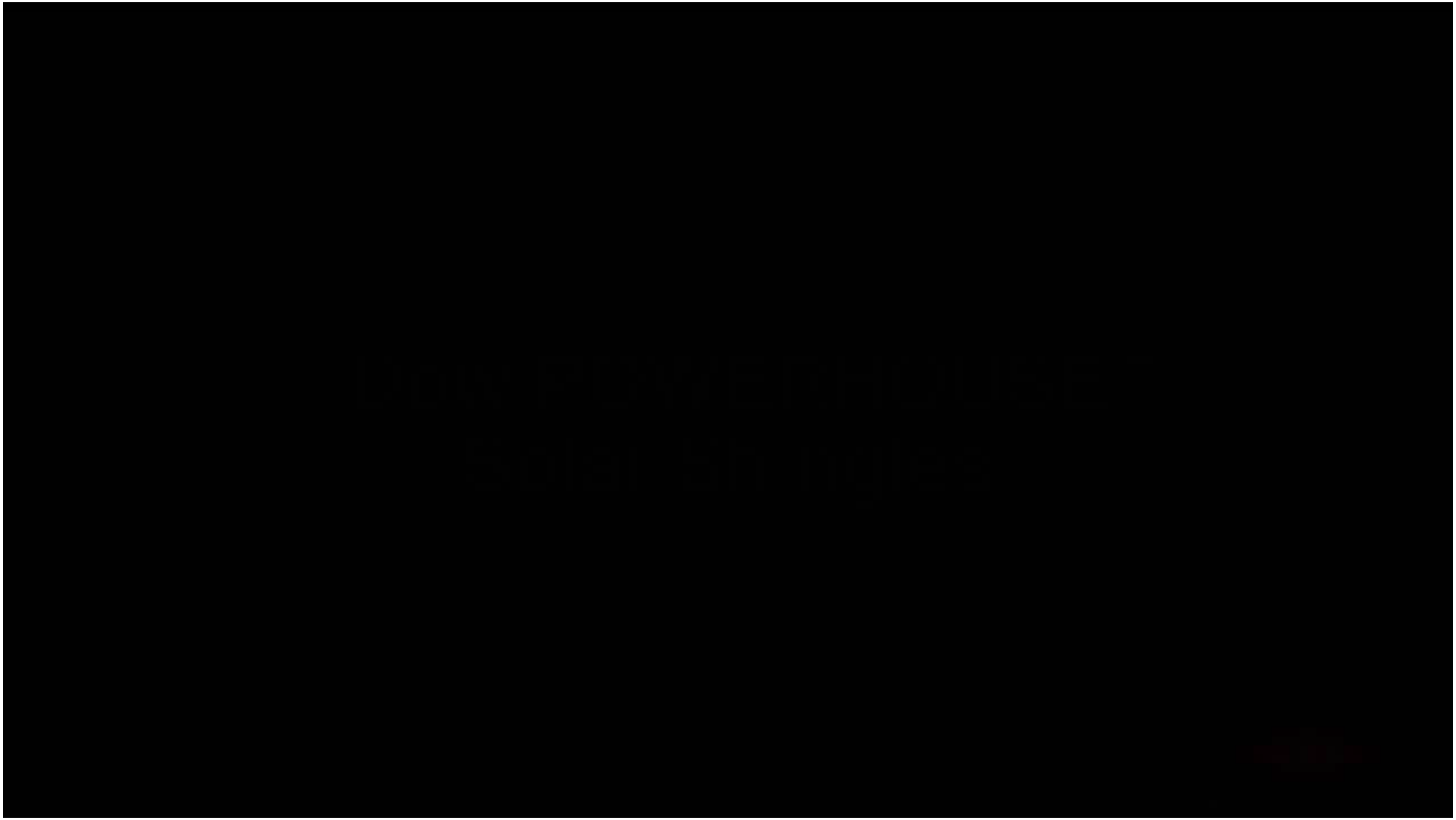
Atlantis SunSlate
- Cost = $13-$15/Watt
- Requires premium roofing slates
- Heavy (Si panels + fiber cement slate)
- Labor intensive

Roof Integrity/Warranty

Installation Complexity

Aesthetics

Head to Head Competition



The Challenges of Supply

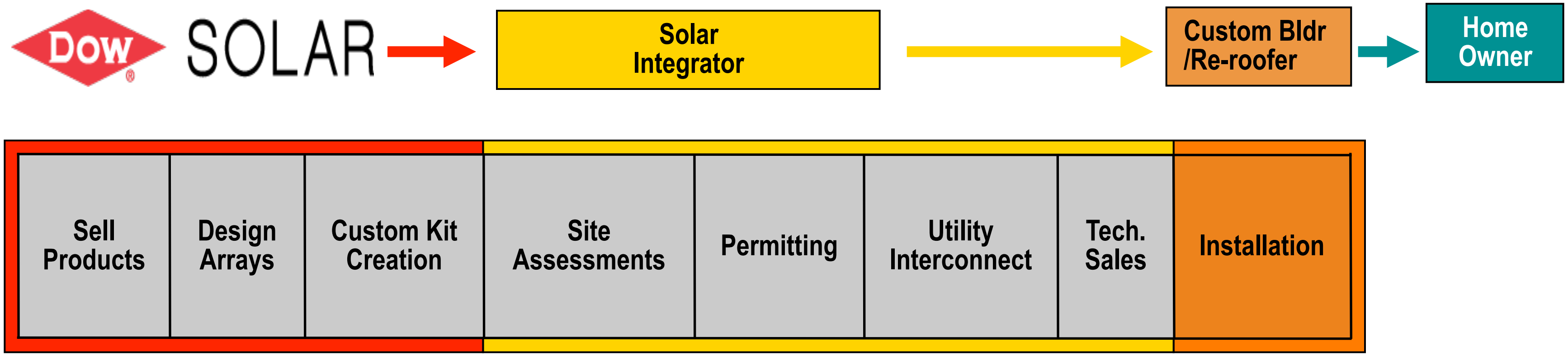
Channel Selection

Builder Direct,
Building Material Distributor,
Solar Integrator

Markets Selection

Reroofing, Retrofit, Commercial,
Residential, New Construction

Example: Solar Integrator / Residential New Construction



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

IEC
MIAMI-DADE COUNTY
CEC Requirements
FSEC
UL Underwriters Laboratories
ASTM INTERNATIONAL Standards Worldwide
ICC ES

UL790 TEST
CLASS A BEST RATING

HANDLING & INSTALLATION

HAIL & INCLEMENT
WEATHER

0445 Plastics
UL 746
UL 514
UL 1703
ASTM DS2843

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

UL 790
UL1897
ASTM E1929
ASTM DS2843

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Success……. Or Failure?

The future of solar has arrived. Introducing POWERHOUSE™. Solar shingles that lay and flex like ordinary asphalt shingles, but create their own energy. Producing up to 80% of the power your home uses. More energy. Less energy costs. Learn more about the world's first solar shingle at dowsolar.com.

20 year life product
Generates profit
Excellent roofing properties
Excellent electricity generation
Strong consumer demand

CAforniacation: @BP_America Youre killing me. Clean up your sh*t and hurry up
about 19 hours ago · Reply · View Tweet · Twitalyze @CAforniacation

dradik27: @BP_America Im avoiding your pumps like the black plague..
about 20 hours ago · Reply · View Tweet · Twitalyze @dradik27

1MiamiHurricane: @BP_America - just a reminder: You Suck! Thanks to tweeps like @buckdenton who send relevant & accurate news on the oil spill. #Fail #Oi
about 1 days ago · Reply · View Tweet · Twitalyze @1MiamiHurricane

jbuford: @BP_America, pls be more social. You only follow yourself, and youre not talking w/ those of us who care about the #oilspill. talk to us!
about 1 days ago · Reply · View Tweet

mattsokoloff: @BP_America Why arent you providing us updates on the spill?
about 1 days ago · Reply · View Tweet · Twitalyze @mattsokoloff

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

Settling Claims

Product-liability suits against car makers have had varying outcomes

COMPANY	PRODUCT		OUTCOME
		ed ge claims	A judge in March rejected a settlement offering $500 coupons and DVDs with fuel-economy tips
GM	Motors pick-up trucks	fuel tanks; suits filed in 1993	Owners given $1,000 coupons toward purchase of a new GM vehicle
Ford	Ford Explorer	Defective Firestone tires could lead to rollovers	$300 and $500 coupons issued in 2008 toward the purchase of new Fords

Source: WSJ reporting

Bloomberg Businessweek

Bloomberg

Toyota Recalls 1.1 Million Cars

August 26, 2010, 10:23 PM EDT

By Angela Greiling Keane

Toyota May Fall to No. 3 With Recalls

Toyota's recalls of more than 8 million cars worldwide may put it behind Ford in the U.S. by the end of the year, according to one researcher.

Estimated share of U.S. auto sales

Before recalls		**Now**	
GM	17.87%	GM	18.12%
Toyota	**17.57**	Ford	16.57
Ford	16.36	**Toyota**	**16.45**
Honda	11.14	Honda	11.32
Chrysler	9.08	Chrysler	9.16
Nissan	7.65	Nissan	7.73
Hyundai	7.12	Hyundai	7.22
Other	13.21	Other	13.43

Source: Edmunds.com

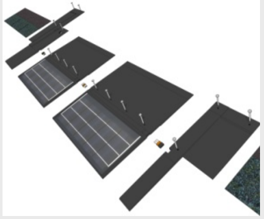
Bloomberg

Reliable Process and Product Design

System

1 Grid tied array

Sub-system



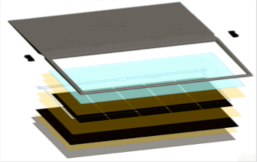
1 Inverter

10's End pieces

100's Power electronics

100's of Shingles

Component

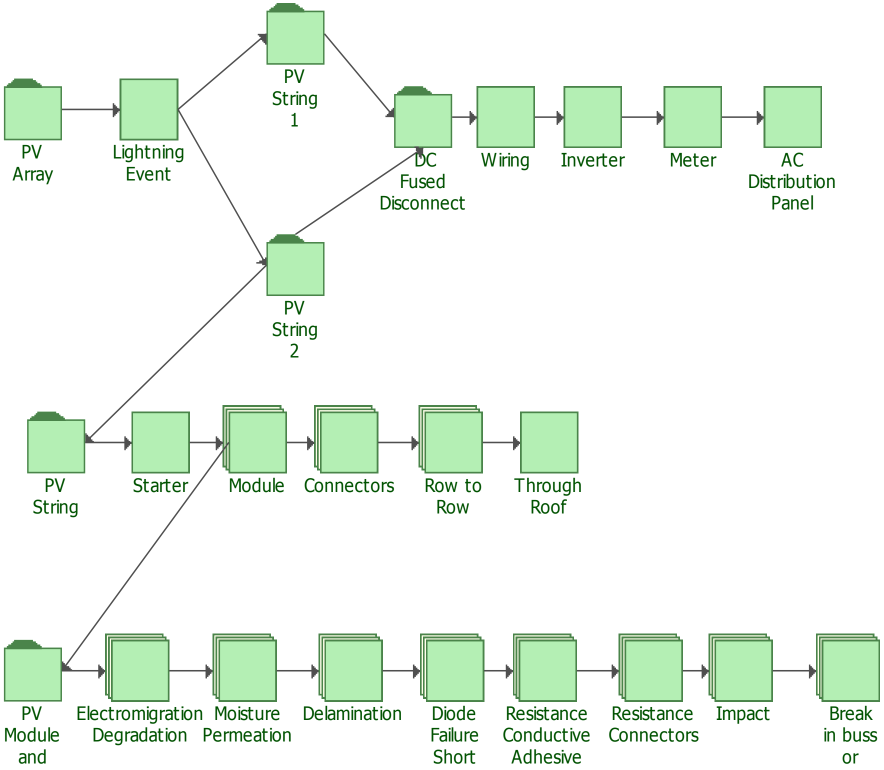


100's of connections

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

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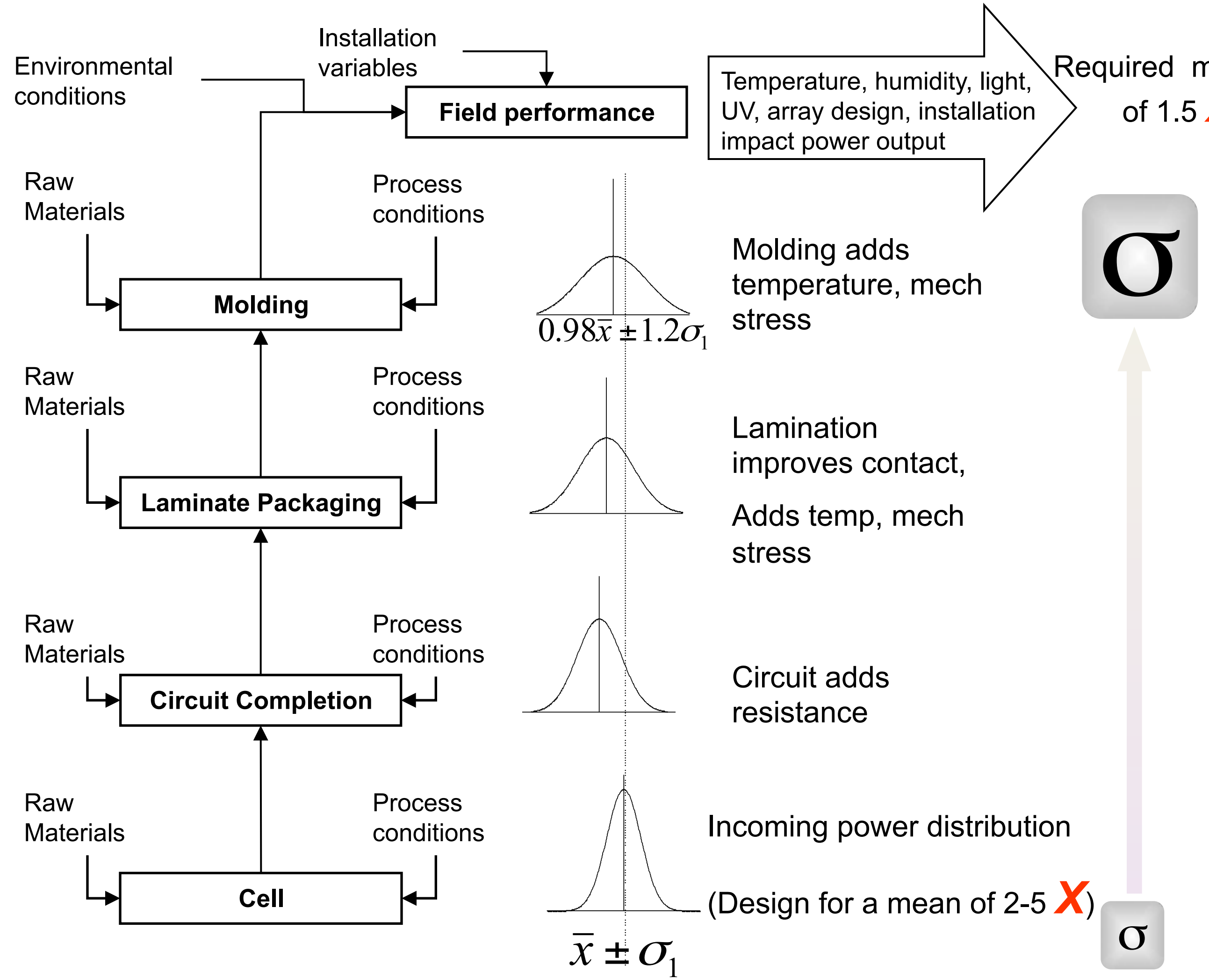
Reliable Process and Product Design

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



Environmental conditions

Installation variables

Field performance

Temperature, humidity, light, UV, array design, installation impact power output

Required mean of 1.5 X

Raw Materials

Process conditions

Molding

$0.98\bar{x} \pm 1.2\sigma_1$

Molding adds temperature, mech stress

Raw Materials

Process conditions

Laminate Packaging

Lamination improves contact,

Adds temp, mech stress

Raw Materials

Process conditions

Circuit Completion

Circuit adds resistance

Raw Materials

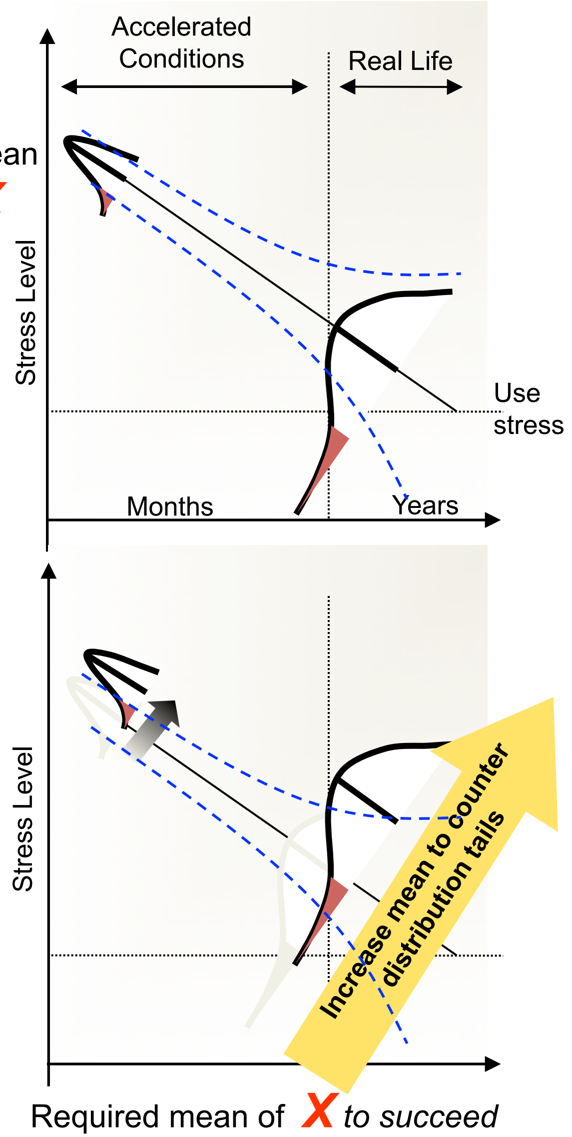
Process conditions

Cell

Incoming power distribution

(Design for a mean of 2-5 X)

$\bar{x} \pm \sigma_1$



Required mean of X to succeed

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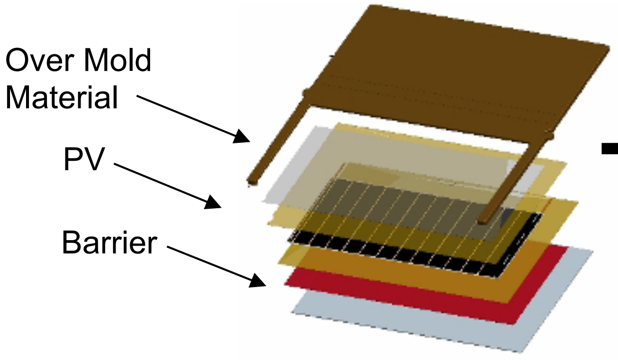
Challenges of Material Design and Selection

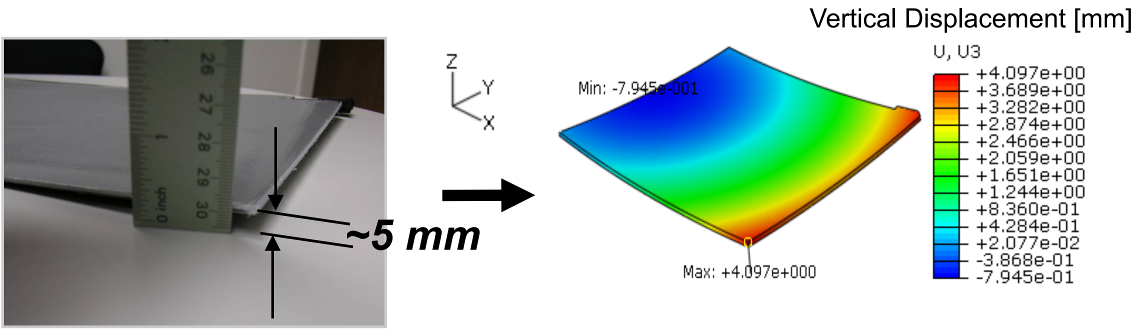
Materials Challenges

- 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

$$\underbrace{\int_S t_i \delta u_i dS}_{\text{Traction Force}} + \underbrace{\int_V f_i \delta u_i dV}_{\text{Body Force}} = \int_V T_{ij} \delta E_{ij} dV$$

The Challenges in Building a Plant

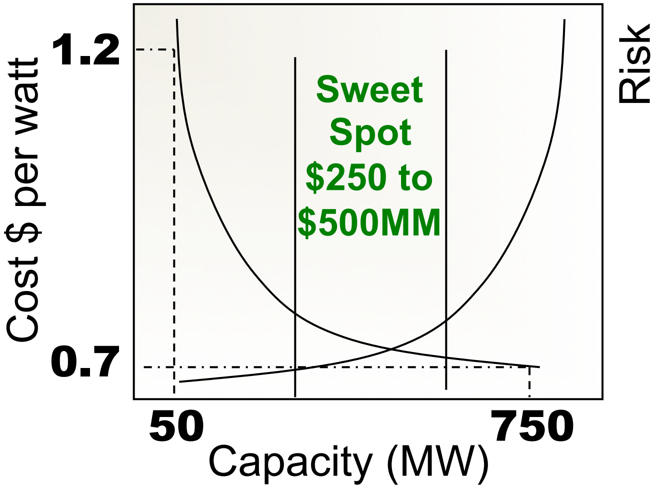
Major Considerations

- 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

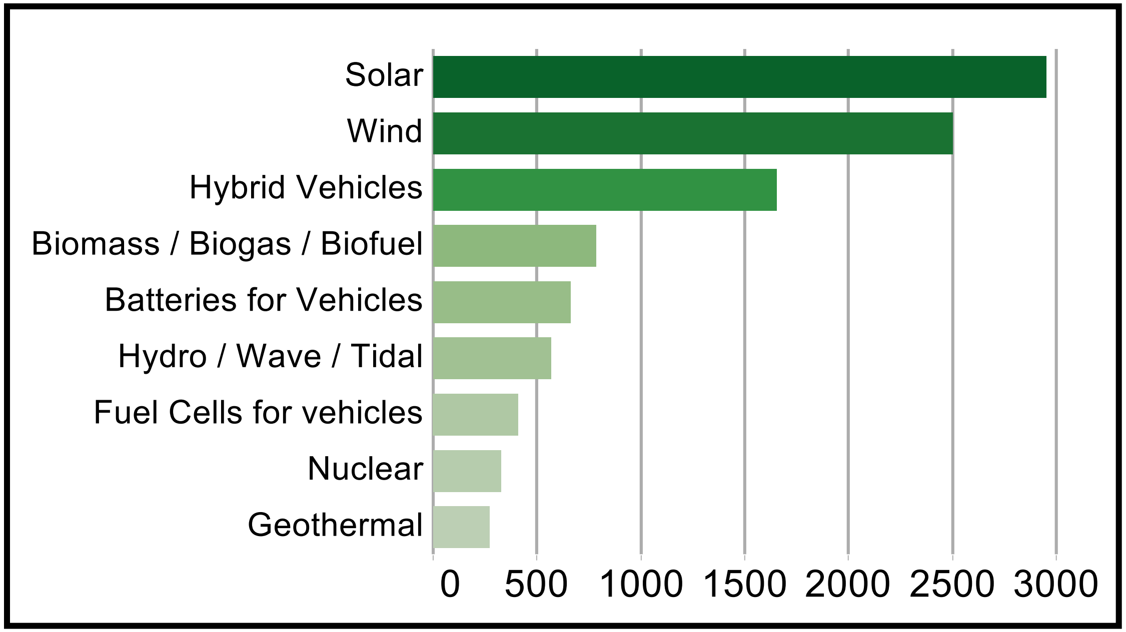
- Larger capacity of first plant means:

– Low module cost	-Lower flexibility
– Standardization	-Higher capital
	-Higher risk
	-Higher base cost



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

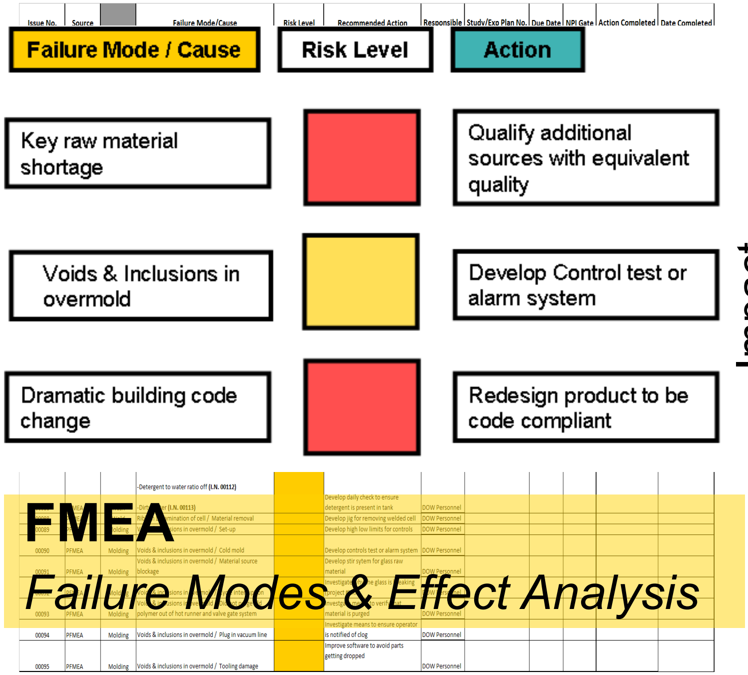
For a single product, Freedom to Operate and IP Requirements include:

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

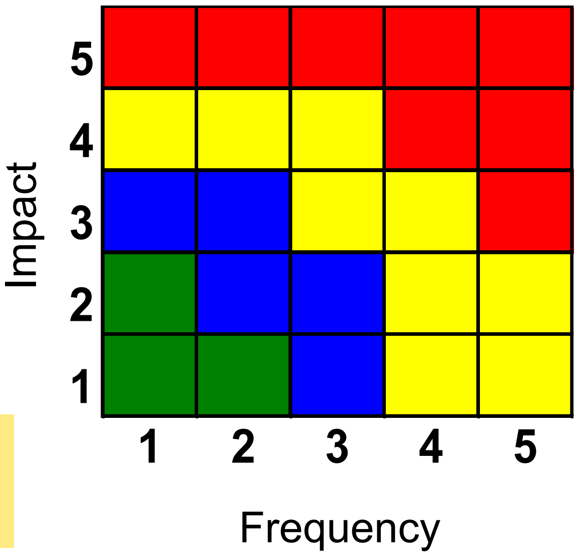


Failure Mode / Cause	**Risk Level**	**Action**
Key raw material shortage	🟥	Qualify additional sources with equivalent quality
Voids & Inclusions in overmold	🟨	Develop Control test or alarm system
Dramatic building code change	🟥	Redesign product to be code compliant

FMEA

Failure Modes & Effect Analysis

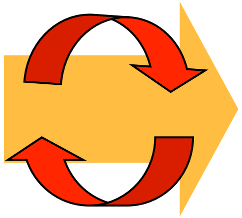
Risk Assessment



Impact					
5	🟥	🟥	🟥	🟥	🟥
4	🟨	🟨	🟨	🟥	🟥
3	🟦	🟦	🟨	🟨	🟥
2	🟩	🟦	🟦	🟨	🟨
1	🟩	🟩	🟦	🟨	🟨
	1	2	3	4	5

Frequency

- Redesign
- Retool
- Rationalize



Launch?

- Verify
- De-Risk
- Certify

0 months ***3 months*** **6 months**

Stress Reduction at the Interfaces

High Modulus Edge	**Interface**	**High Modulus Frame**

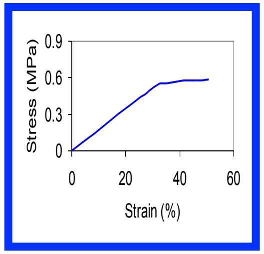
Quantify and minimize strain at interface

Options

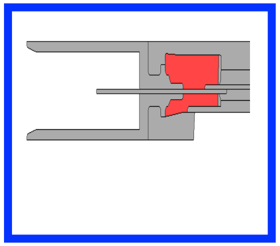
FEA

Results

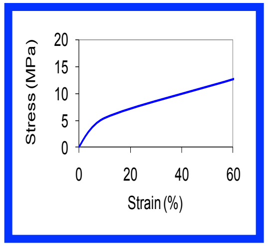
Material A



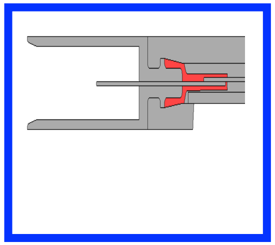
Design 2



Material B

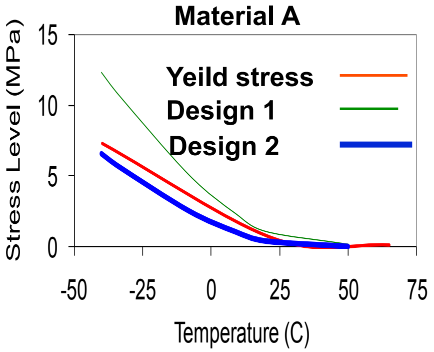


Design 1

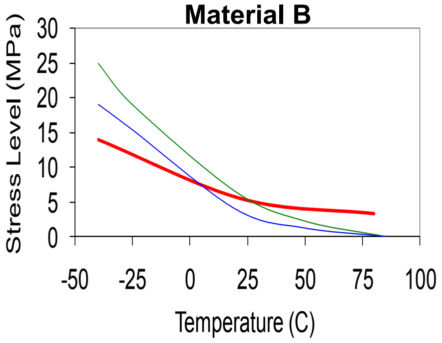


Materials

Designs



Material A



Material B

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

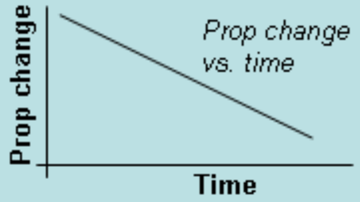
Explore Design-Material space to reduce stress at critical interface

Calculating Acceleration Factors

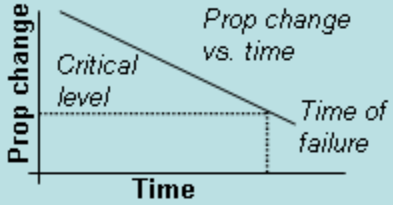
1. Determine stress levels → for ex. 3-5 levels of temperature

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

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



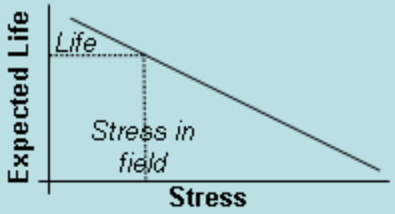
3. Determine failure point at each stress level & calculate time to failure at each stress level



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

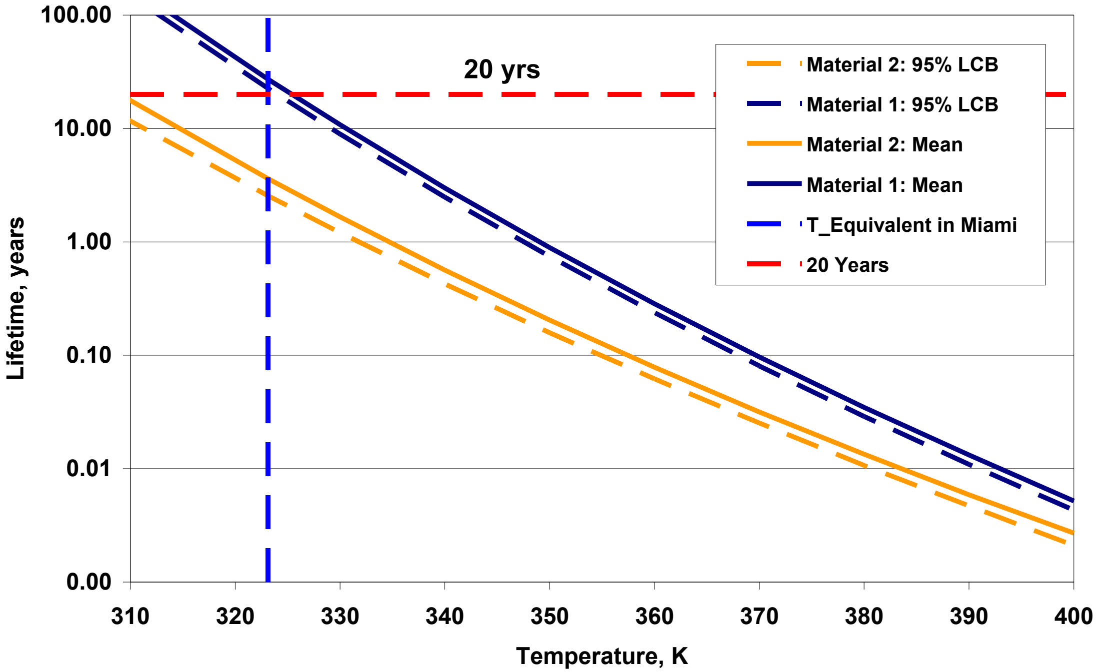
   - Sum degradation using field data
   - Calculate equivalent exposure stress

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



Hydrostable Material Selection

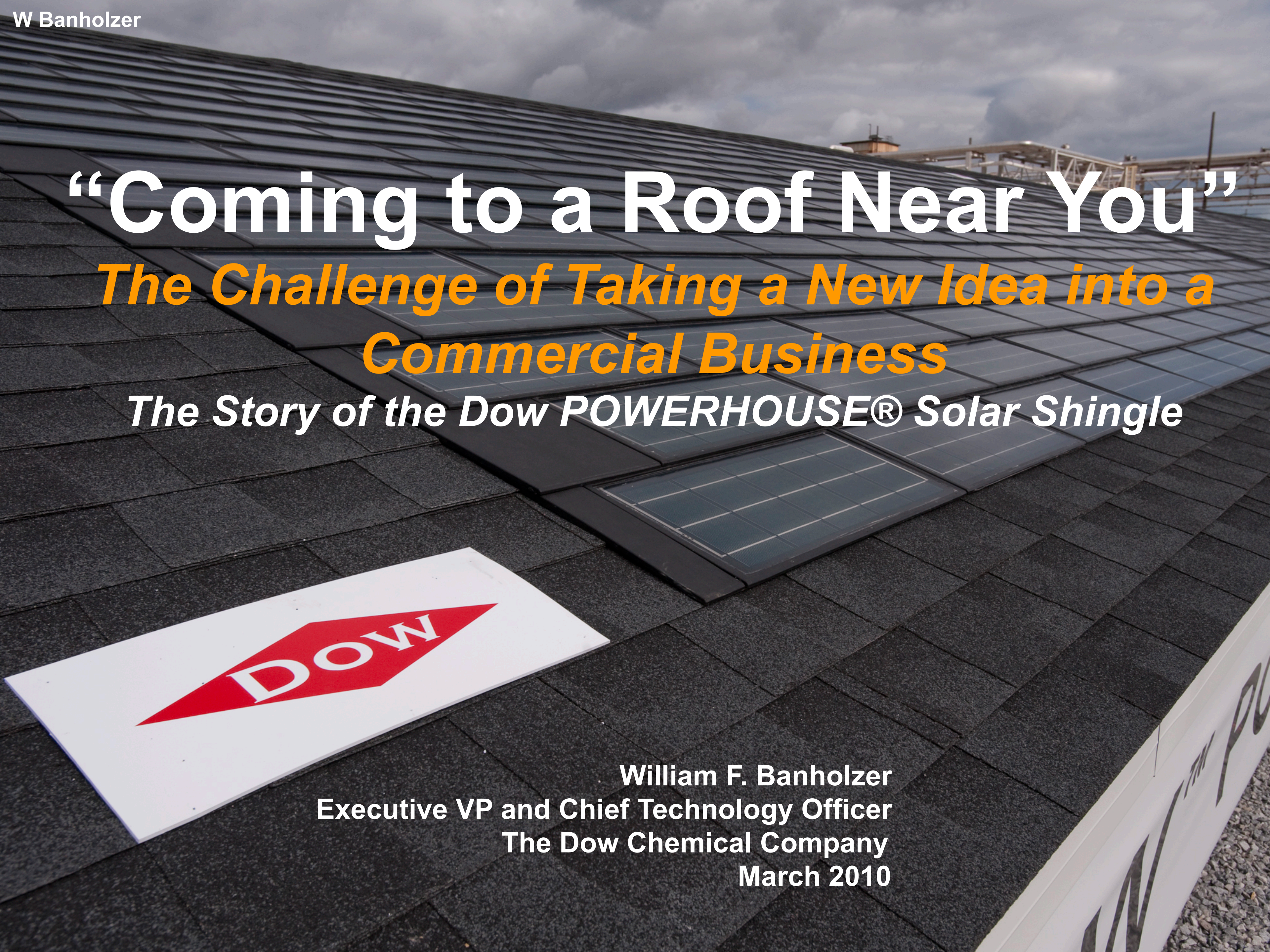
Material lifetime analysis at 99.9999% reliability



- 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 inadequare
- 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

Thank You



“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