PHOTOVOLTAIC MANUFACTURING CONSORTIUM
PVMC

U.S. PV Manufacturing and Opportunities for Florida

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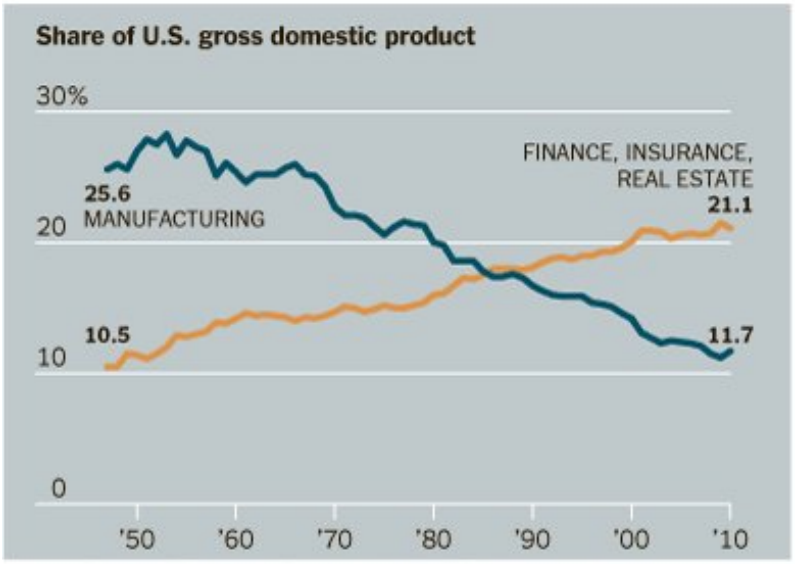
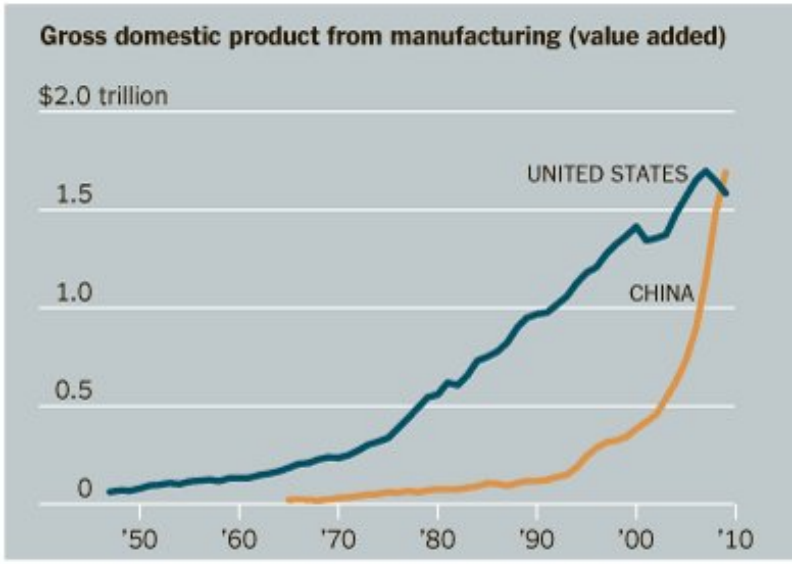
Manufacturing Share of Gross Domestic Product

- U.S.: 11.7% China: 25%
- By Comparison it was 28% in U.S. in 1950's

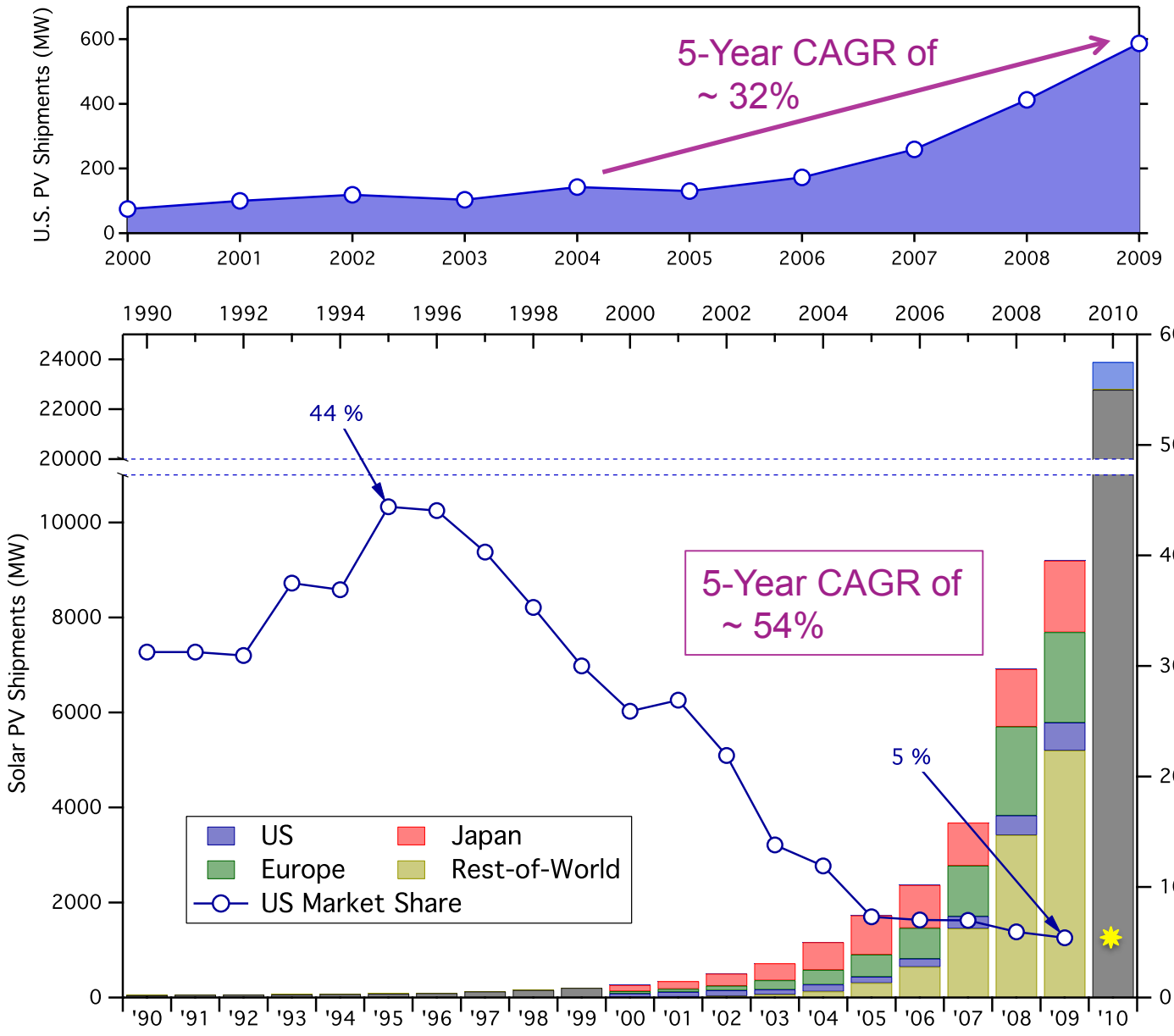




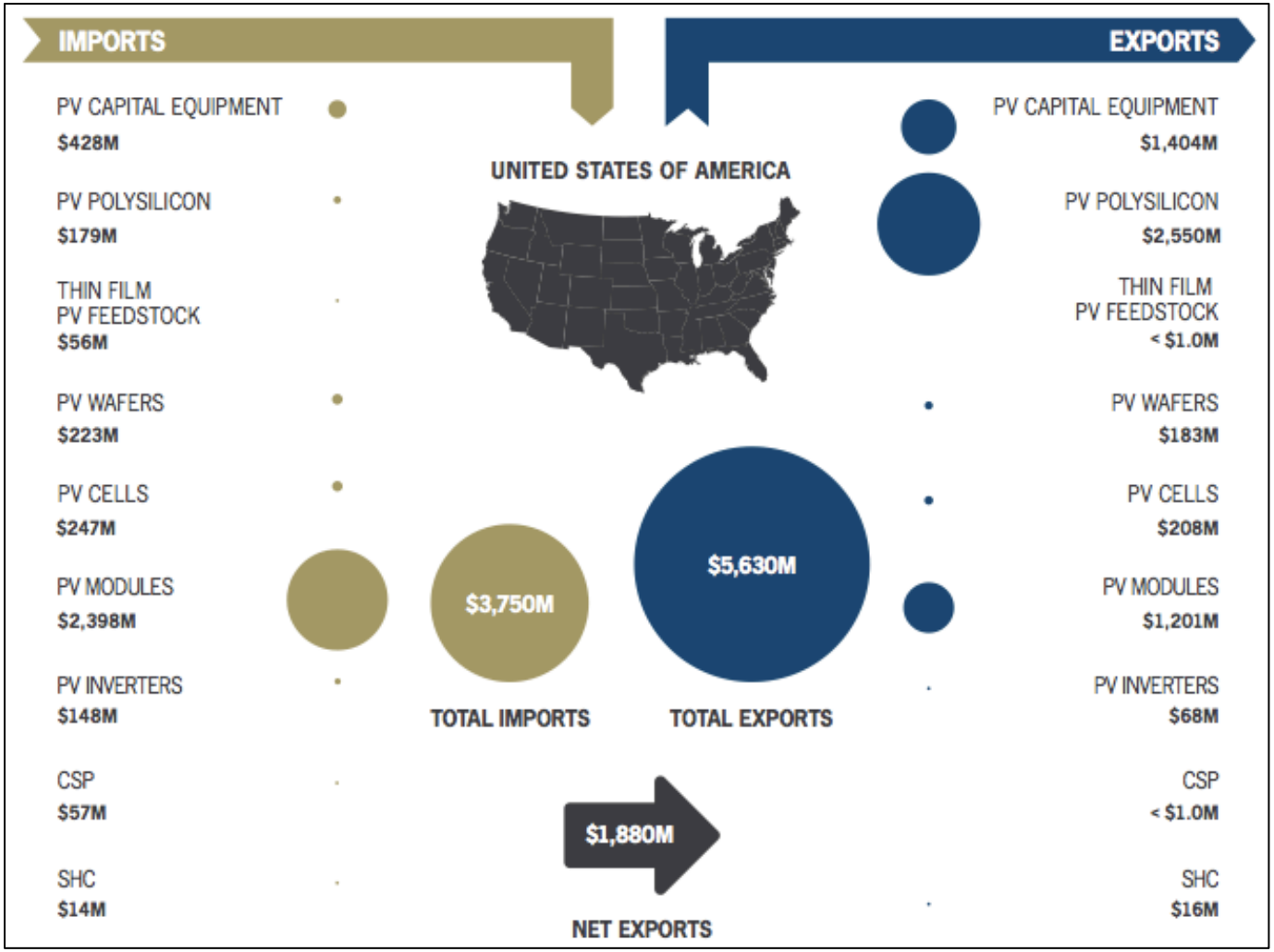
Sources: Bureau of Economic Analysis; the World Bank

- Note: Not due to reduced manufacturing, but rather slower growth rate.
- Why care? General estimates are that every new manufacturing job generates 5 other jobs in the economy.

The History and Status of U.S. PV Manufacturing



Manufacturing is not just Cells/Modules



Market Share

40%

3%

4.6%

3%

Note: U.S. had $247M trading ***surplus*** with China

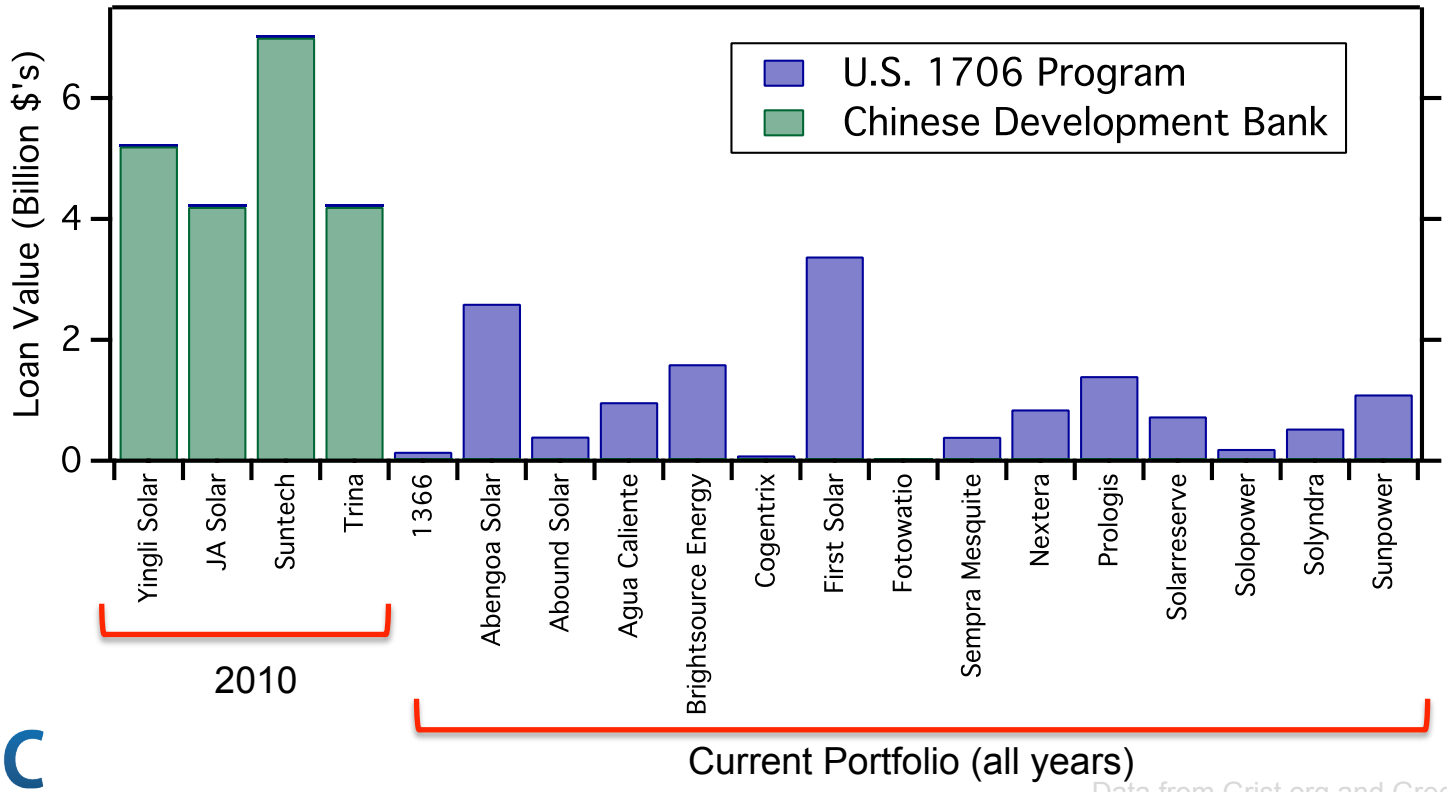
PVMC

10 November 2011

** Taken from GTM Research/SEIA Publication

Government Support of PV Manufacturing
(loan guarantees)

- U.S. - Section 1705 of the 2005 Energy Policy Act
  - $15.6B in loans (*$10.5B for solar*), but ~$1B in 2010
- China - China Development Bank (CDB)
  - $30B in 2010 loans



Data from Grist.org and Greentech Solar

Is there another way to maintain/grow U.S. PV market share?

- Government Loan Guarantees are not enough

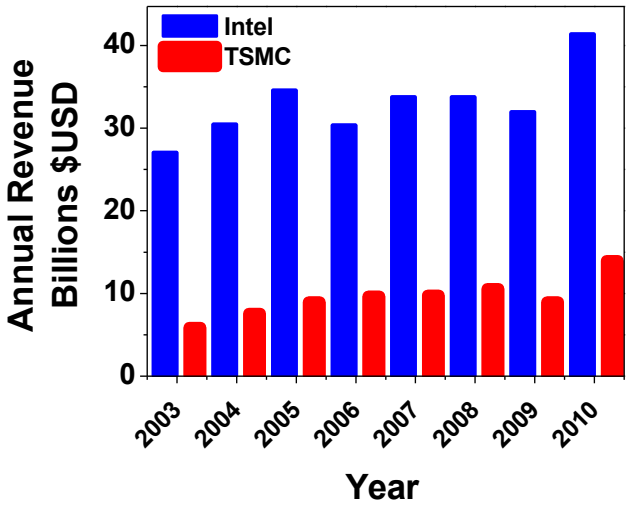
- Need Multiple support structures
  - Capital costs
  - Bankability (finance)
  - Strong/talented work force
  - Proximity to innovation
- Loan Guarantees address first item

- Is there another complimentary route for U.S. PV market share growth?

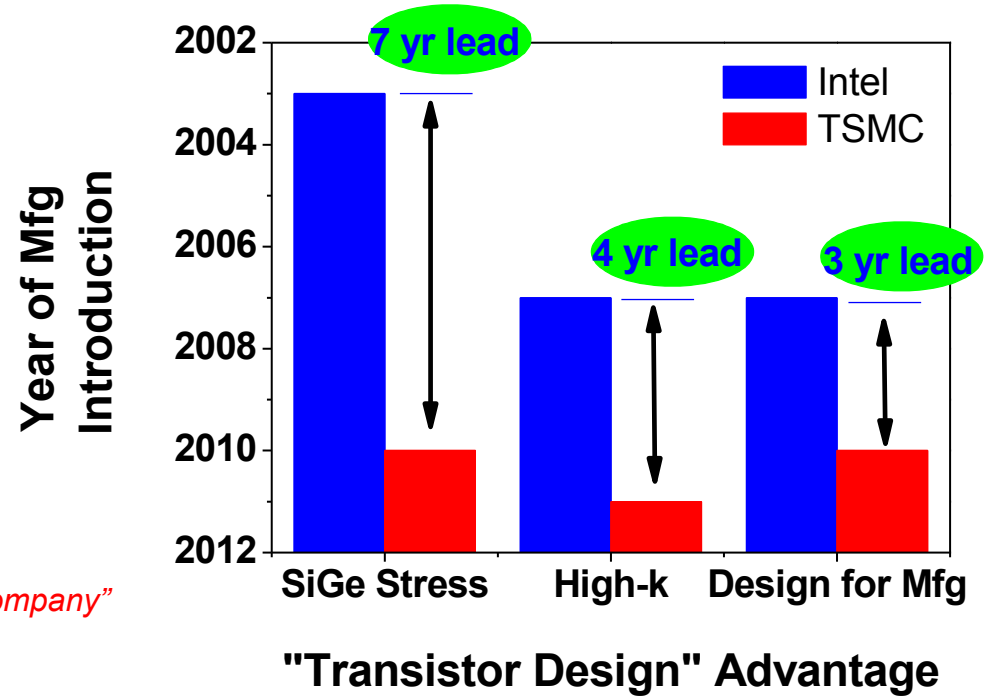
Can technical innovation drive U.S. market share?

Question: *Why has Intel has led IC industry for 19 years?*

Answer: 3-7 years Transistor technology lead – 50-100% pricing power.



TSMC – "Taiwan Semiconductor Manufacturing Company"



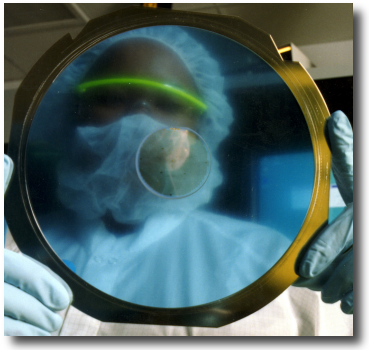
- SEMATECH Led Industry to ALD HfO_2 as High-k – Intel adopted novel integration
- IMPACT: Intel's competitive edge results in ~ $100B revenue from high-k HfO_2

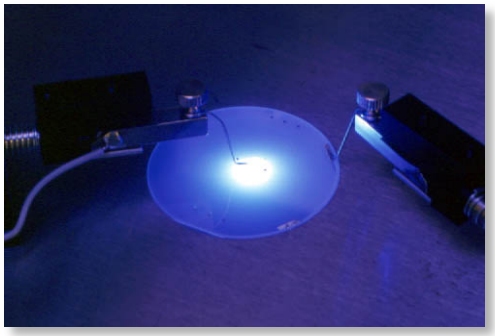
My experience - A snapshot of the LED industry

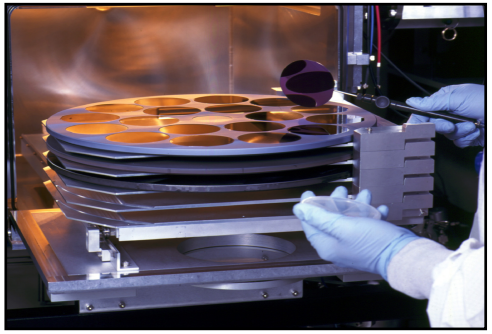
- In 2000, there were many U.S. LED companies
- Common price of blue LED chip $0.20 - $0.30
- Two years later price was $0.05 - $0.10

- Cause: Despite rapid market growth, Asian manufacturing (i.e. supply) grew faster.
- Result: Only handful of major LED U.S. manufacturers remain.

- Common Denominator: All invested in technical innovation, allowing them to stay ahead of commodity curve.



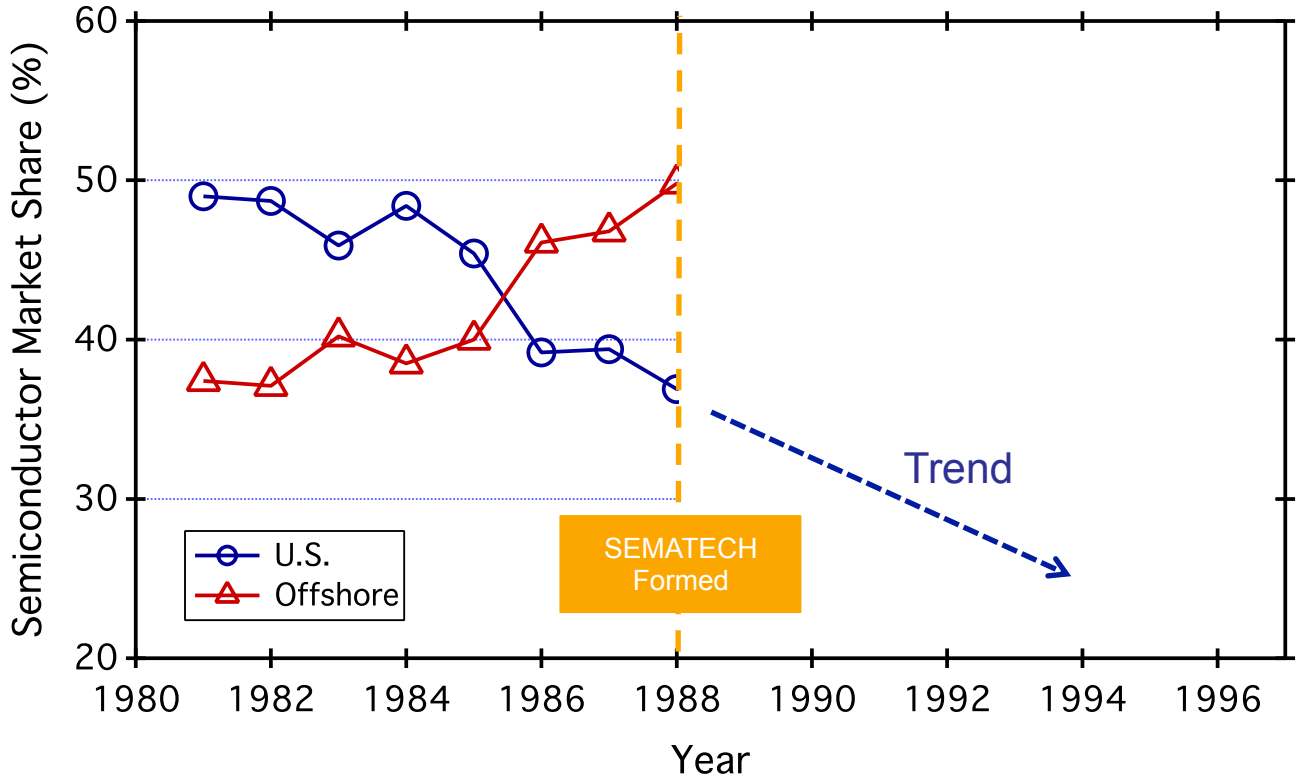




Some History from Semiconductor Industry

"The most significant finding of the Task Force is that U.S. ***technology leadership*** in semiconductor manufacturing is rapidly eroding and that this has serious implications for the nation's economy and immediate and predictable consequences for the Defense Department."

- Defense Science Board Task Force on "Semiconductor Dependency" - ***February 1987***

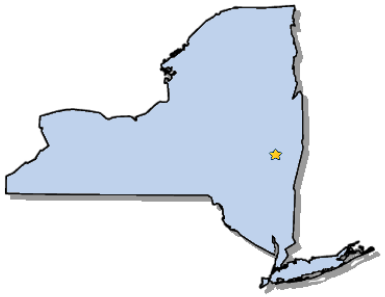


U.S. Photovoltaic Manufacturing Consortium (PVMC)

- DOE decided it needed a similar SEMATECH model for the PV Industry
- Led by SEMATECH in partnership with CNSE (College of Nanoscale Science and Engineering) and UCF (University of Central Florida)
- Overall investment of ~$300M over 5 years from DOE and matching funds
- Initial focus on CIGS and cSi technology and manufacturing solutions

SEMATECH

Consortium Management

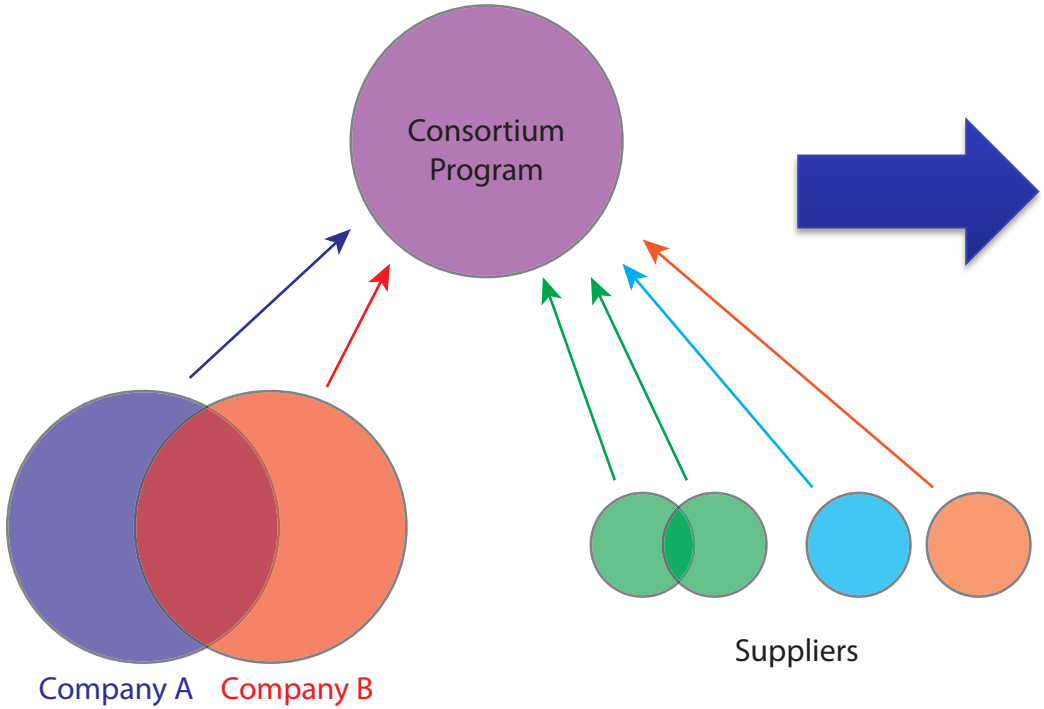


CIGS

cSi

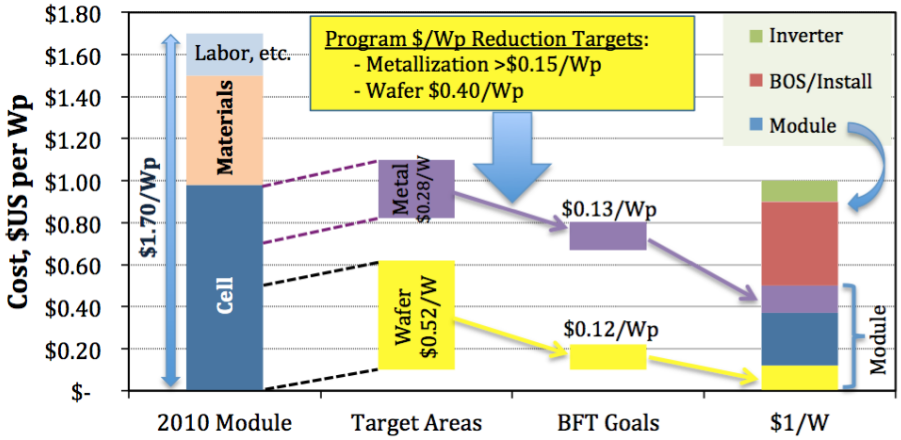
Key: Establishing *Collaborative* Consortiums

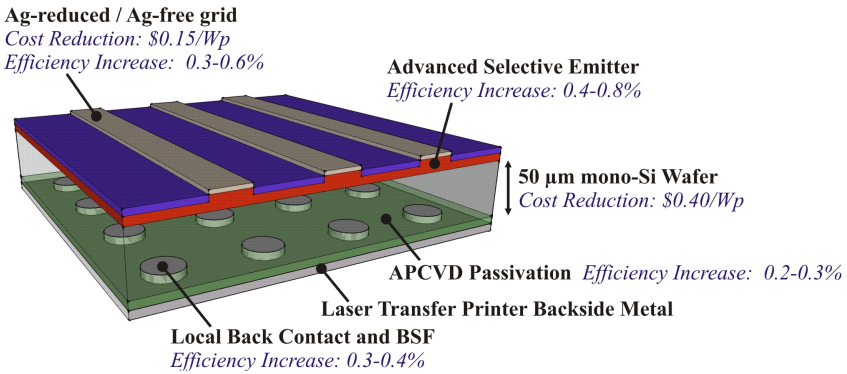
- PV Industry is historically fragmented
- How do you get consortium members – even direct competitors – to work together?



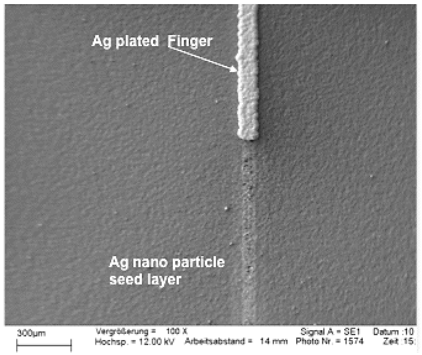
Distributes Risk & Cost
Accelerates Progress

Example Program: 50µm SE cSi Cell





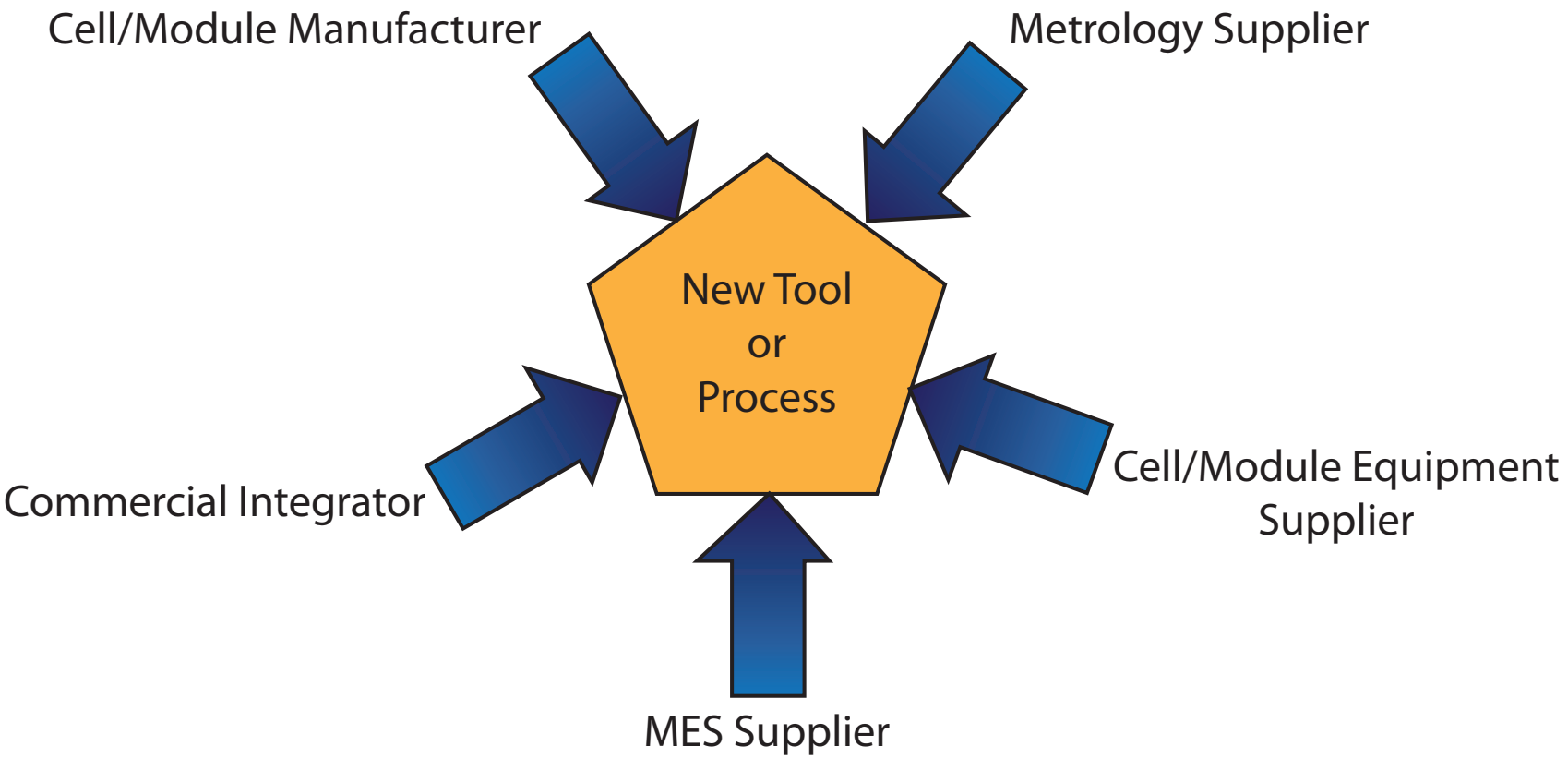
Industry	- 50 µm mono cSi Wafers - Non-contact metallization equipment for Front Grid and LBC - Backside passivation [illegible] equipment (ex. APCVD) - New stringing [illegible] processes for thin wafers - Electropla[illegible]mistries and b[illegible]
Academia	- Rheolo[illegible] studies for nanoparticle seed layer - Front g[illegible]id geometry optimization - Seed la[illegible]er optimization - LBC st[illegible]s (opening method, diameter/spa[illegible], etc…)
National Labs	- Reliability studie[illegible] - Validation of performa[illegible]ce - Field testing



LIP System

What is a β-Site?

Example Project: Integration of inline carrier lifetime mapping after P-diffusion, communicating with MES using SEMI PV 02 Standard



Initial PVMC cSi Program Areas

1. In-line/Off-line Metrology

Primary Goals

- Identify critical industry needs in metrology and rank
- Develop projects to demonstrate new cSi metrology technologies
- Transition new metrology technologies into pilot and manufacturing lines

Current 5-Yr Program Area Goal (revision expected by WG)

- >1,100 wf/hr in-line tool, reducing yield loss such that cost of insertion is offset completely

2. New Feedstock/Wafering Methodologies

Primary Goals

- Identify necessary feedstock/wafering targets for $/W
- Establish cSi feedstock/wafering programs to accelerate transition of new technologies into mainstream manufacturing
- Provide and foster process, test, and demonstration activities to validate new technologies and identify technical barriers

Current 5-Yr Program Area Goal (revision expected by WG)

- Demonstrate silicon usage efficiency < 3g/W and cSi wafer cost reduction of >50% to below $0.25/W.

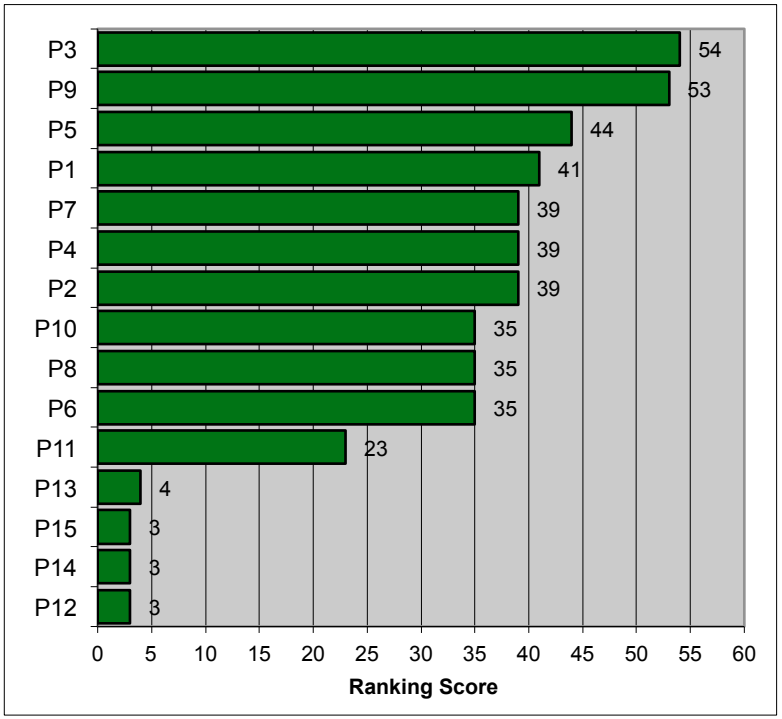
These two program areas are currently supported in FL through $14.3M of DOE and industry/partner matching funding

So…How are projects identified?

Projects driven by identified areas of need

- **Consortium members identify program area projects (working groups)**

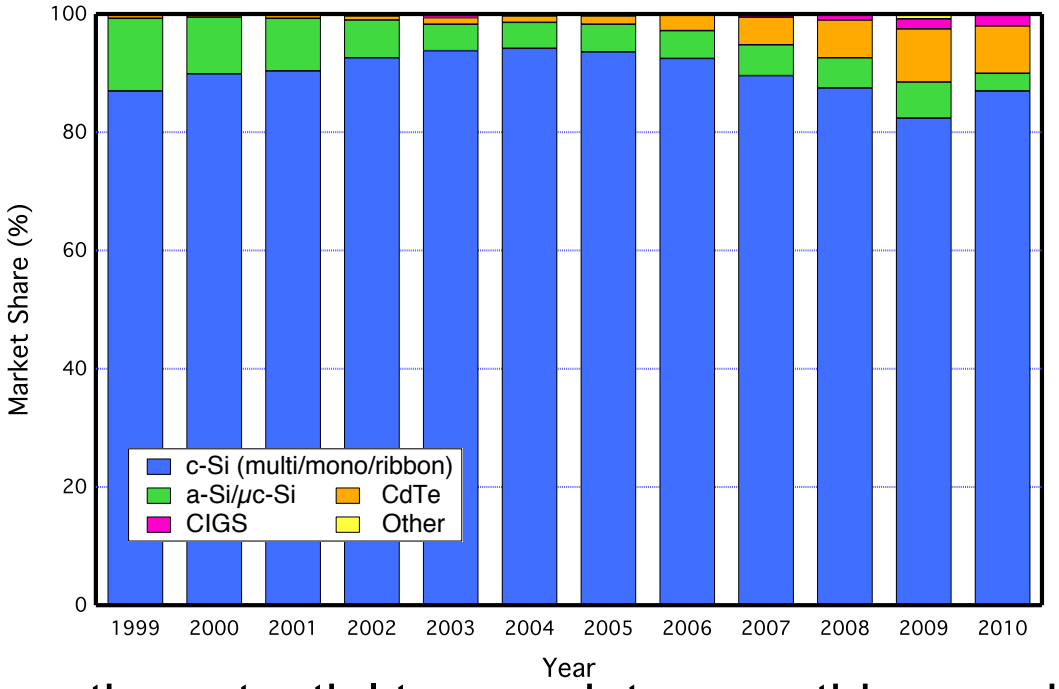
Cell Projects	
P1	Selective Emitter (inkjet/self-aligned, etc.)
P2	SiO_2/SiN ARCs (Multi-layer or graded SiON)
P3	Advanced Cell Structures (all back metal, emitter/metal wrap-through, n-type wafers)
P4	Ag Contacts (non-contact, lower width, etc.)
P5	Ag-free Grid Metallizations & Electroplating
P6	Texturing (IPA free, dry texturing, high aspect ratio, etc.)
P7	Enhanced Surface Passivation Methods (aqueous ozone)
P8	Correlation Study (offline data to yield, h, performance distribution, etc.)
P9	In-line Metrology Tool Development
P10	Thin Wafer Handling, Statistics, "Moore's Law" cost model for PV
P11	Simulation: wf thickness, bulk doping, emitter doping, Rco
P12	Integration of n-type or Ga doped p-type wafers into existing processes
P13	2D and 3D modeling of advanced cell structures (local contacts, adjacent n and p regions)
P14	Grain boundary and surface passivation
P15	Alternate surface passivation techniques (eg. Silicon carbide, negative charge dielectrics)



- **Identical paretos for feedstock/wafering, modules, and manufacturing productivity.**
- **Program area ranking allows prioritization of projects and selection of asset allocation**

So….What is the Unique Opportunity for Florida ???

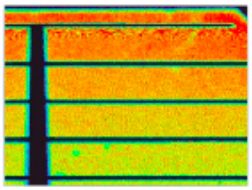
- Currently, Florida is one of only 2 states running the first U.S. PV manufacturing consortium
- Florida houses the cSi arm of the PVMC – a conversion technology that has maintained 80% market share for over a decade.



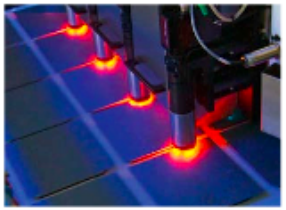
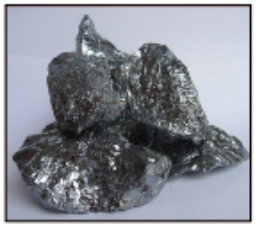
- We have the potential to grow into something much larger….

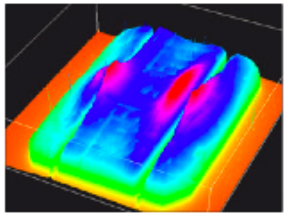
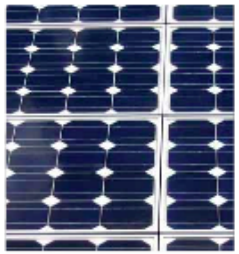
Supply Chain Strength in the U.S.

PVMC-FL can build from ***existing*** U.S. leadership in several areas of the cSi PV supply chain – smaller barrier for growth and job creation





R&D Partners	Material Suppliers	Equipment Suppliers	Metrology Suppliers	Module Producers and Integrators	End-Users
- IBM - NREL - ORNL - SRC - NIST - ASU - SUNY - UCF	- SRI - Sandia - Sandia - SEMI - ISMI - MIT - UCLA - FSEC	- MEMC - ATMI - 1366 - Crystal Solar - JT Baker - Saint Gobain - Solsil - Dow	- Orion - 3M	- Schmid - Spire - TEL - Roth & Rau - Varian - Ulvac - Consarc	- Semilab - Boeing/Spectrolab - FEI - Keithley - Agilent - Newport - Ultrasonic Tech - KLA	- Suniva - Ampulse - Intersil - SemiSouth - Solar Power Ind. - Calisolar	- FP&L / NextEra - Lockheed Martin - Progress Energy - Austin Energy - TSEC

Must Expand Programs to Include the Diverse Supply Chain

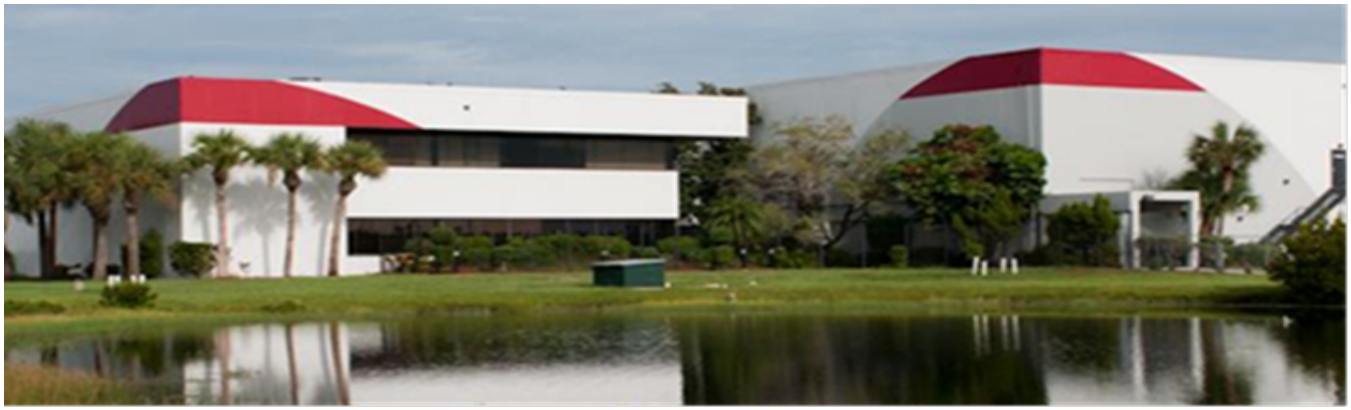
What the U.S. cSi Industry Needs

The challenge	The PVMC solution
Industry alignment	Roadmap and standards
Lack of infrastructure	Collaborate to fund and create it
Lack of place to work	Advanced manufacturing development facility
Metrology, tes nd reliability	Develop, model, and share capabilities
Manufacturing st – CIGS and cSi	Improved methods = reduced cost
Balance of sys m, technology commercializa n, workforce development	Support to the industry
Cost of PV en y to consumer	Consortium = shared knowledge and resources and reduced cost of manufacturing = reduced cost to consumer

PVMC cSi Manufacturing Development Facility is Essential

Expansion of PVMC-FL – Phase II

- **Establish Next-gen RD&C Manufacturing Facility**



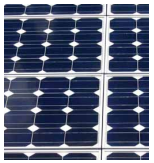
  - 100,000 ft^2 site already available in Palm Bay, FL
  - Next-gen cSi wafer-to-module *manufacturing*-scale lines for Consortium Projects
  - Critical value-added element of PVMC for industry, houses consortium and member company projects.

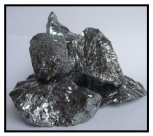
Expansion of PVMC-FL – Phase II

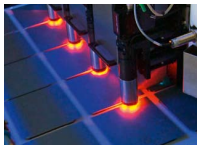
- **Establish Next-Gen RD&C Manufacturing Facility**
  - 30 MW Cell and Module Manufacturing Line for Consortium Projects
  - Advanced and Next-gen tools sets
- **Establish PV Commercialization Support Structure**
  - Support transfers into manufacturing, provide incubation and start-up support
- **Develop Training Workforce Development Programs**
  - College, university, MDF, and member company programs
- **National cSi Roadmap and Standards**
  - Identify industry drivers, establish Executive Steering Committee/Working Groups
- **Expansion of Consortium Programs (Next Slide)**

PVMC-FL – Expansion Opportunity

- Build from existing PVMC-FL to expand program areas and increase member company value.







Cross-cutting

Cell	Selective Emitter (inkjet/self-aligned, etc.)
	Advanced Cell Structures (all back metal, emitter/metal wrap-through, n-type wafers)
	Ag-free Grid Metallizations & Electroplating
	SiO2/SiN ARCs (Multi-layer or graded SiON)
Module	New Encapsulation Materials
	Optimized cell connectivity in module
	Smart Modules (integrated self-diagnostics, power electronics)
	Easy Install Designs (weight, time)
	Better Stringing/Tabbing Schemes
Feedstock \ Wafering	Develop Incoming Wafer Specifications and In-line Metrology
	Evaluate Siemens Process Alternatives
	Lifetime Evolution - Correlate w/ Process History
Manuf. Productivity	Equipment Standardization (software, communication)
	Establish SPC and APC Systems for Improved Yield and Reliability
	Industry Benchmarking to Establish Manufacturing Best Practices
Other	Roadmap and Standards
	PV Commercialization Support Structure / Incubation
	PV Workforce Development
	Test and Certification

Benefits to Florida

- Establish Florida as cSi Manufacturing Hub of the U.S.
- Brings manufacturing technical challenges to University researchers
- Establishes a magnet for industry, bringing companies to the Florida doorstep

"The SEMATECH Effect"

Value of Long Term Advanced Technology Partnerships

Economic Impact Study

SEMATECH and New York

- Home to International SEMATECH HQ, the manufacturing arm of SEMATECH
- Attracted more than $3.2 billion dollars in capital investment for AMD microchip plant
- Created nearly 500 high-tech, high-wage immediately
- Supporting more than 500 companies across the state as key anchor of Albany Nanotech Initiative

U.S. scaled estimates – more that 3.1 million permanent jobs

SEMATECH and Texas

- Played a critical role in national security initiative
- Key driver of the launch of Texas as a leading high-economy
- Attracted more than $12 billion dollars in capital investment
- Created more than 80,000 high-tech, high-wage jobs Texas
- Leader in government technology & economic development policy and investment

Semiconductor R&D has a multiplier effect of five (highest of all industries) resulting in an additional 400,000 ancillary jobs

U.S. Scaled Estimates

Based on U.S. capturing same share of global market as Texas captured in U.S. market, annual economic impacts of:

- $482.8 billion in expenditures
- $235.4 billion in gross domestic product
- $141.8 billion in personal income
- $50.3 billion in supported retail sales
- More than 3.1 million permanent jobs

AngelouEconomics
GLOBAL ECONOMIC DEVELOPMENT

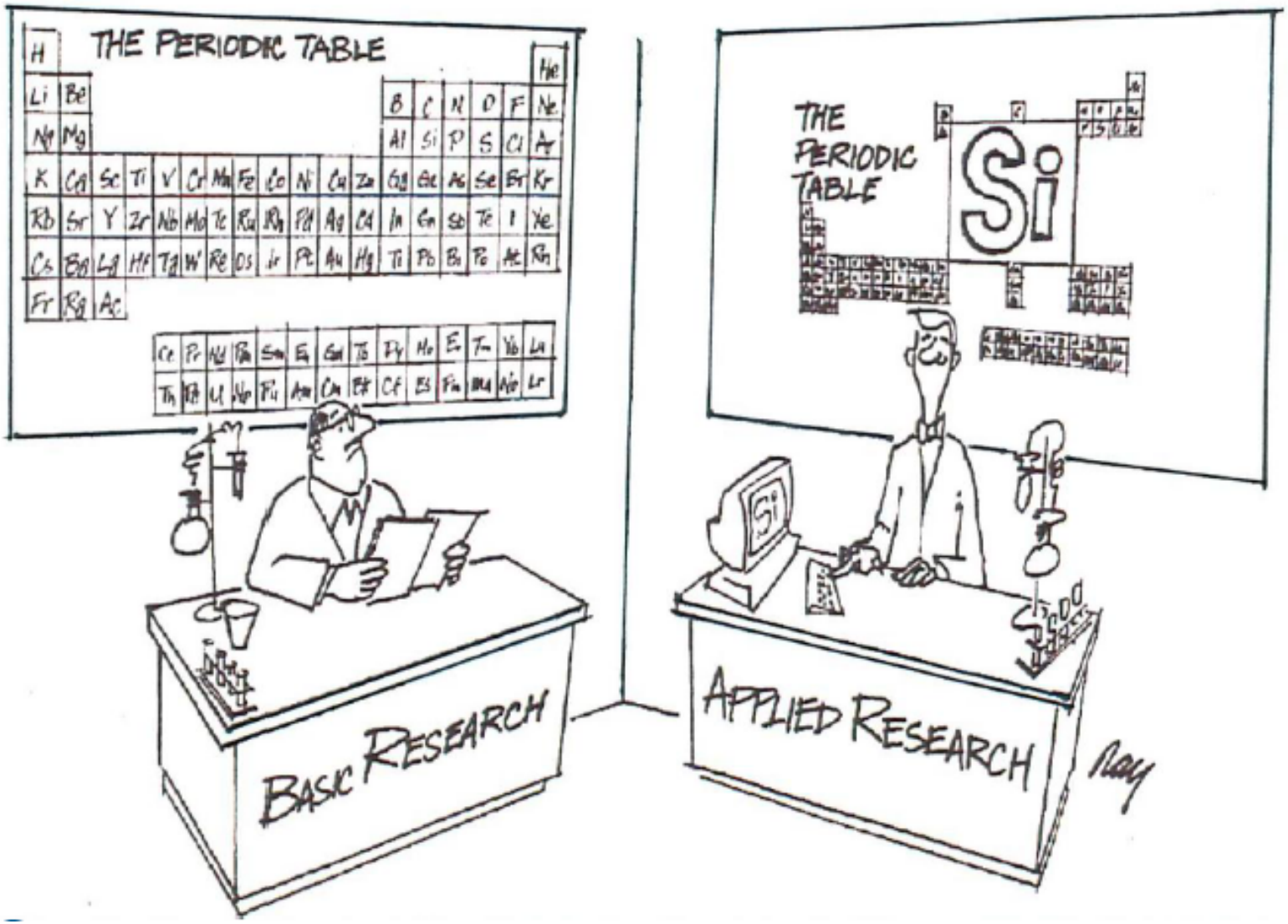
"[SEMATECH North is] the most exciting development since the construction of the Erie Canal."

New York Governor George Pataki SEMATECH North ribbon cutting, 2003

[SEMATECH and the AMRC] will advance the technologies that will help drive our state's economy for the next 50 years.

Texas Governor Rick Perry AMRC Launch

A little humor to end with…



Thank you for your attention !!!

Photovoltaic Industry Overview

- Why is solar energy and PVMC important?
  - Quality of life/environment - most abundant renewable energy source
    - Plentiful energy for the planet while preserving natural resources/ecosystem
    - Potential scale/availability of solar energy
    - Potential uses of solar PV technology
  - Economic – market potential, contribution to economic growth, job creation
    - Solar energy will soon develop into one of the world's largest industries - generating billions of dollars of revenue, and creating millions of high paying jobs
  - National – opportunity for US leadership in technology innovation and manufacturing
    - The clean energy race is well underway - energy technologies not only need to be invented in America, but also manufactured in America
- What are the challenges for the solar market?
  - Levellized Cost of Electricity (LCOE), ***¢/kWh***
    - System **cost**, system **efficiency**, system **reliability**
  - Business challenges
    - Bankability. etc
  - National/Regional challenges
    - Funding needed to establish the foundation and catalyst
    - Weak and declining manufacturing market share
    - Industry alignment