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FUTURE OF (US) PV MANUFACTURING: APPLIED MATERIALS PERSPECTIVE

National Academies/DOE
April 23, 2009

APPLIED MATERIALS.

Applied Materials Overview

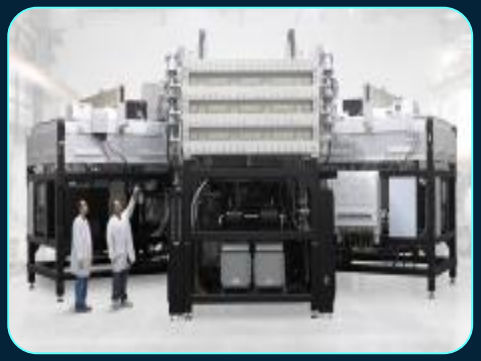
Applied Materials is the global leader in Nanomanufacturing Technology™ solutions for the fabrication of:

- Semiconductor chips
- Flat panel displays
- Wafer & TF solar photovoltaics
- Flexible electronics
- Energy efficient glass

Net Sales (past 4 qtrs.)	**$7,357 M**
incl. Energy & Env Solns	**$989 M**
RD&E (rolling 5 years)	**$5,312 M**

Worldwide Locations

- **21 Countries, ~100 locations**
- **Headquartered in Silicon Valley**
- **Manufacturing in Europe, Israel, Asia and United States**

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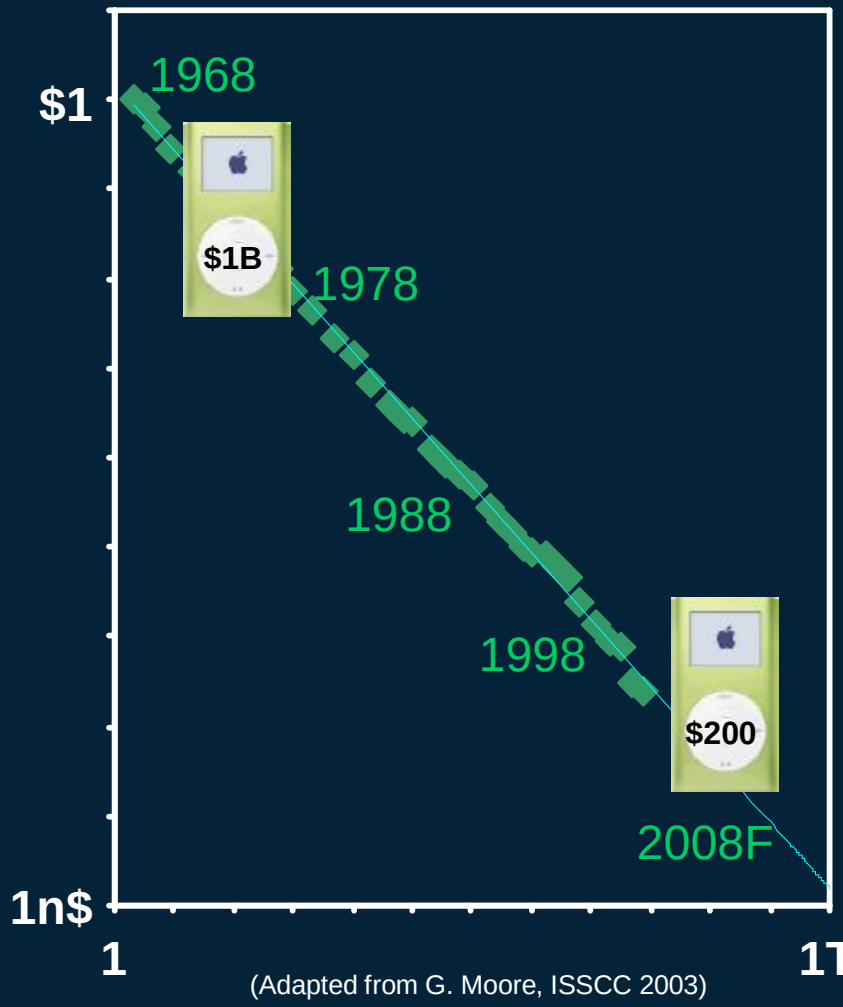
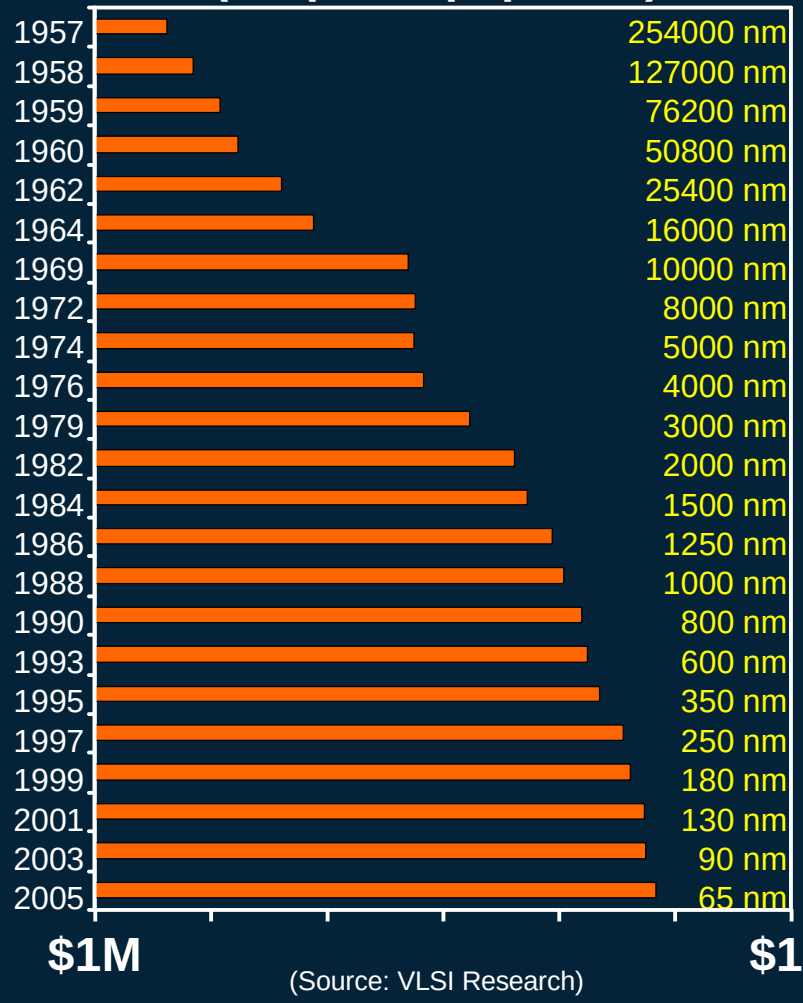
Moore's Law and VLSI Learning Curve

Cost per Transistor vs. Number Produced



(Adapted from G. Moore, ISSCC 2003)

WW R&D Spending Per Node (Chip & Equipment)



(Source: VLSI Research)

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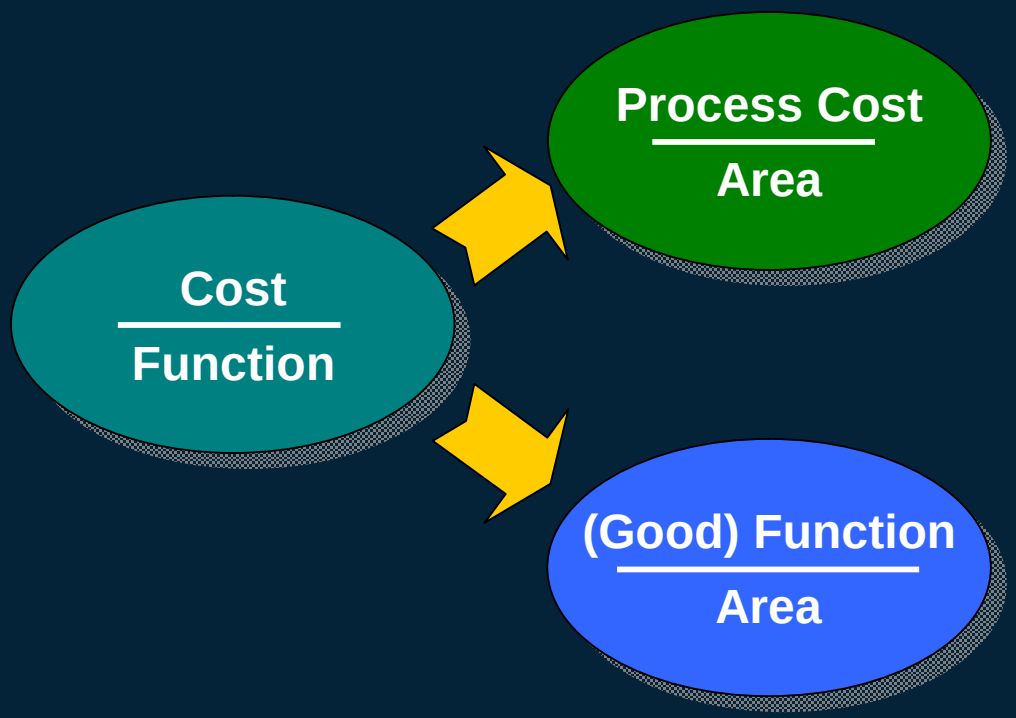
Cost Per Function Drivers & Lessons

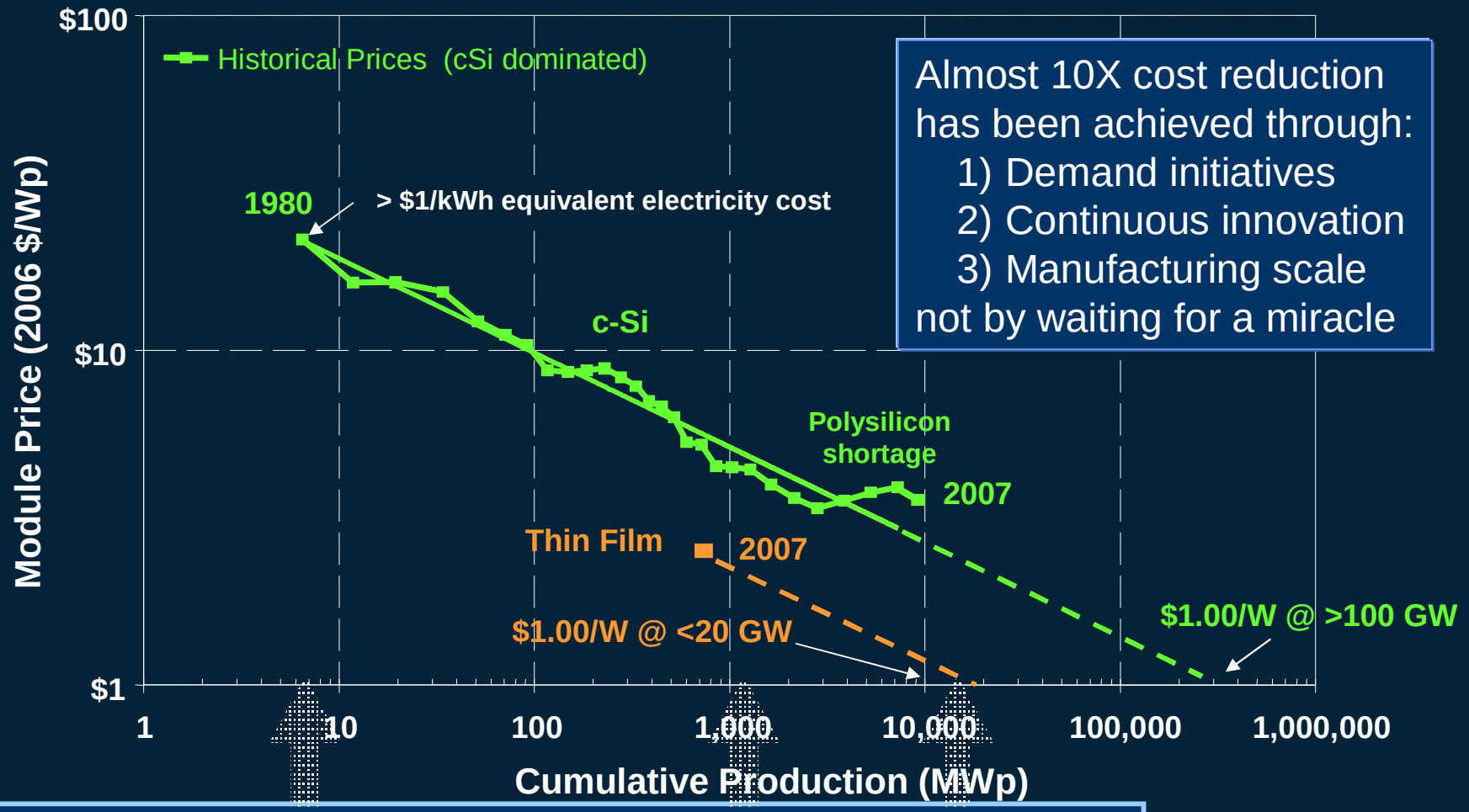


Substrate Size & Cost
Tool Productivity
Consumable Costs
Utility Costs
Factory Scale
Line Yield
Factory Management

Materials Innovation
Process Innovation
Process Uniformity
Device Design
Closed Loop Control

- Nanomanufacturing technologies underlie IC and FPD cost & adoption
- Demand "waves" have been critical to continual investment & progress
- Some level of standardization is important to gain critical mass
- Large area tooling can be a major factor when process cost is significant
- Factory sites do not necessary imply manufacturing technology ownership

Solar Learning Curve: Module Cost/Watt



Almost 10X cost reduction has been achieved through:
1) Demand initiatives
2) Continuous innovation
3) Manufacturing scale

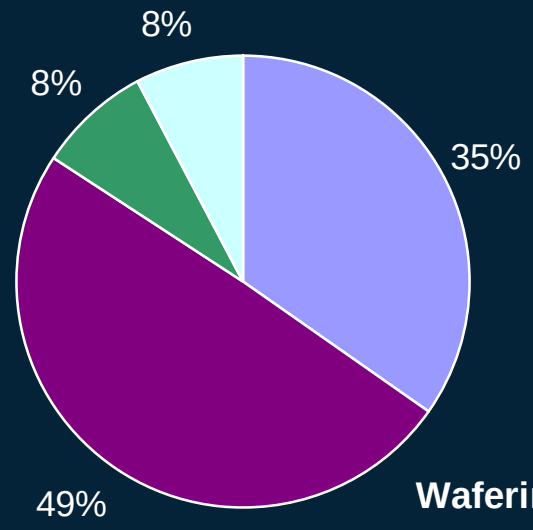
not by waiting for a miracle

Production line size (Megawatts per Year)	0.5 (1980)		5 (2000)	50 (2005)	100 (2010)
Lines Per Factory	2		3	4	10

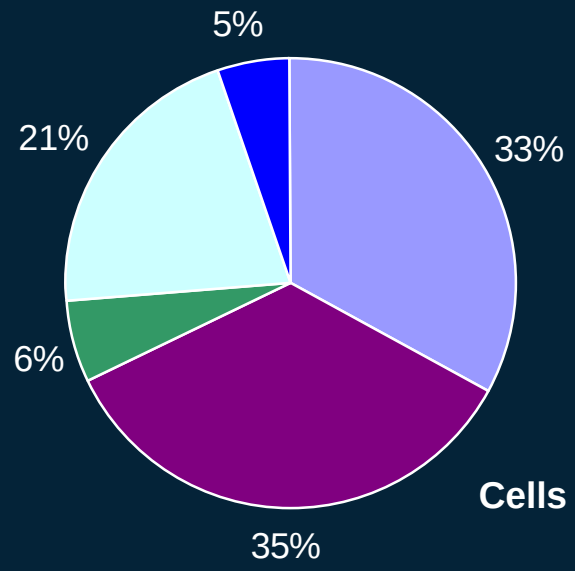
Source: Adapted from NREL

c-Si Wafer-Based PV Manufacturing

Top 20 Capacity-Add Plans By MW (2008+)



Wafering

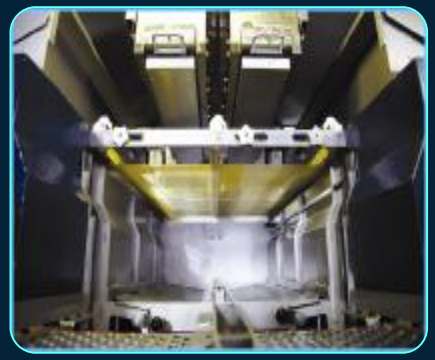


Cells

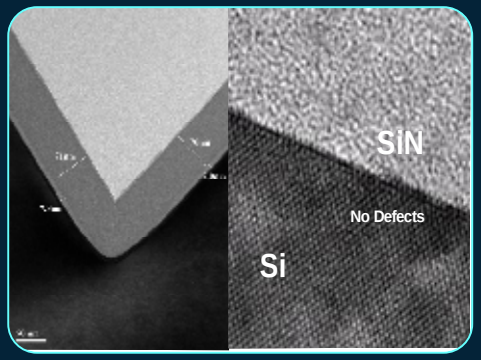
(by HQ Location)

- Europe
- China
- Japan
- Other Asia
- US

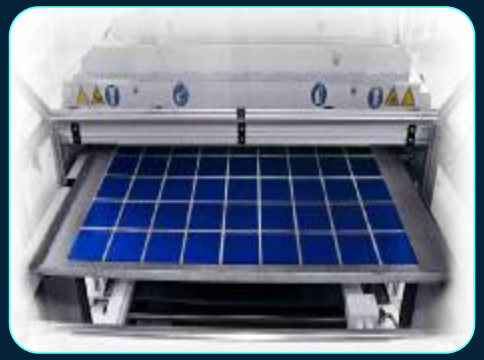
(as of 10/08)



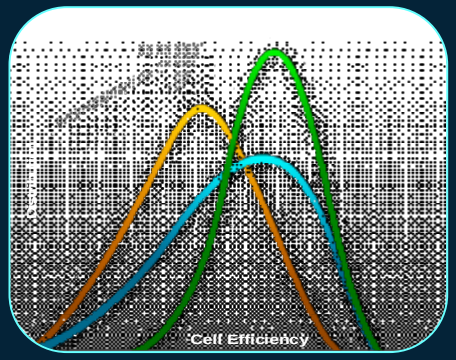
Thin Wafers



Adv Cells/Processes



High Throughput Tools



Factory Control

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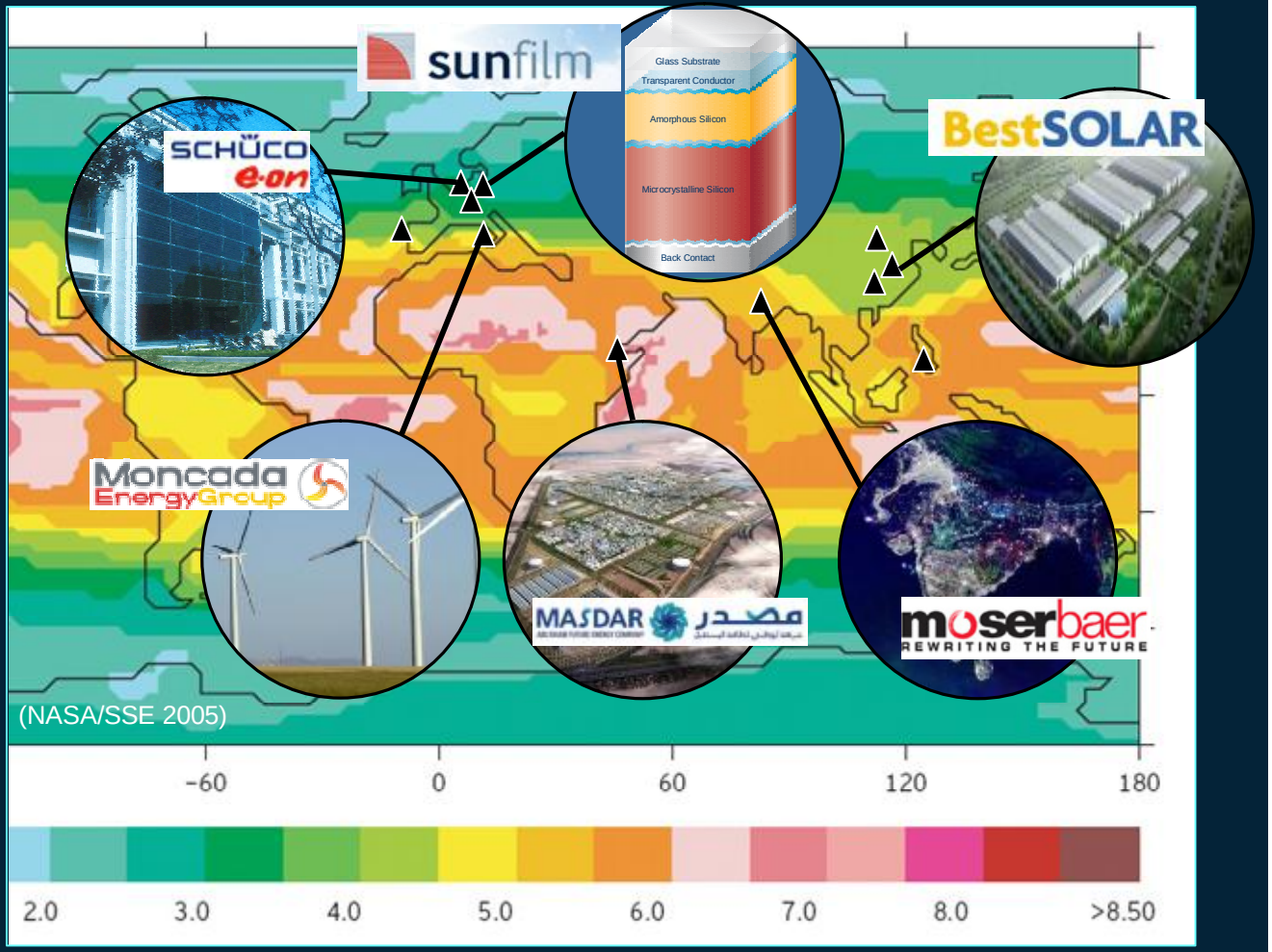
Applied SunFab Production Line Contracts

SunFab™ 5.7m2 TF Module Factories



First Contract Signed in 2007, 14 Projects, 5 Sites in Production

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GW Scale SunFab TF PV Module Factory

Consumes 500 tons of glass per day

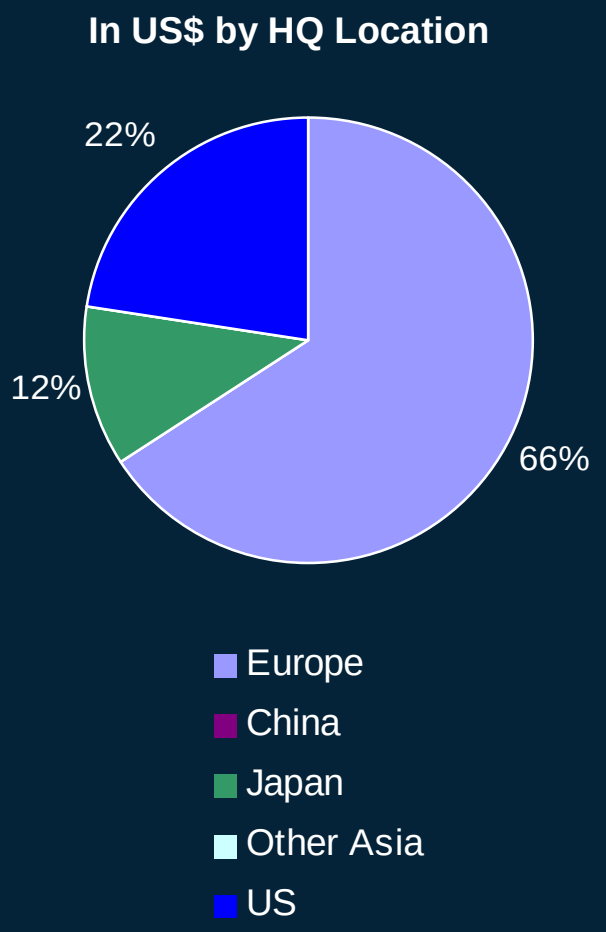
PV factory (111 acres) is larger than the Magic Kingdom at Disney World (107acres)

Produces 6,000 modules per day or enough to cover 7 ½ football fields **per day**

20% Cost/W Reduction From Scale is equivalent to:
~ 1 Year Earlier Parity or 1%+ module efficiency gain

2008 Top 10 PV Cell + Module Manufacturing Equipment Suppliers

1.	Applied Materials (US)	$455M
2.	Roth & Rau (Germany)	$275M
3.	Centrotherm (Germany)	$270M
4.	Oerlikon (Switzerland)	$250M
5.	Ulvac (Japan)	$240M
6.	Manz Automation (Germany)	$140M
7.	Schmid (Germany)	$125M
8.	Von Ardenne (Germany)	$120M
9.	RENA (Germany)	$85M
10.	3S Solar Systems (Switzerland)	$70M



(Source: VLSI Research, Feb 2009)

What Could Help Grow US PV Manufacturing?

- Demand side is the key
  - Account for true future cost – time of day/year, fossil fuel cost uncertainties, carbon cost, value of distributed power
  - Multi-year generation contracts which can average forward module costs
  - Progressive – and enforceable – renewable electricity standards
  - Appropriate cost mechanism for carbon
  - Refundability of renewable credits
  - Clean energy bank for low interest loans on solar projects
- Manufacturing/R&D specific initiatives
  - Renewable manufacturing incentives
  - Collaborative government, industry, university R&D with appropriate balance of evolution vs. high risk/disruption

Applied Materials' newly completed solar energy system in Sunnyvale, CA is one of the largest corporate solar power installations in the US

"If a guy took out a piece of glass, poured some fluid on it, held it up to the sun and got some voltage off it, he made a headline and got funds. Those days are over. It's time for big money commitments."

– J. Robert Maxwell, Westinghouse Director of Solar Programs as quoted in an article by Thomas L. Friedman in The New York Times, Aug 1981.

Now really is the time…