Solar Photovoltaics

Presentation to DOE Solar Hydrogen Workshop

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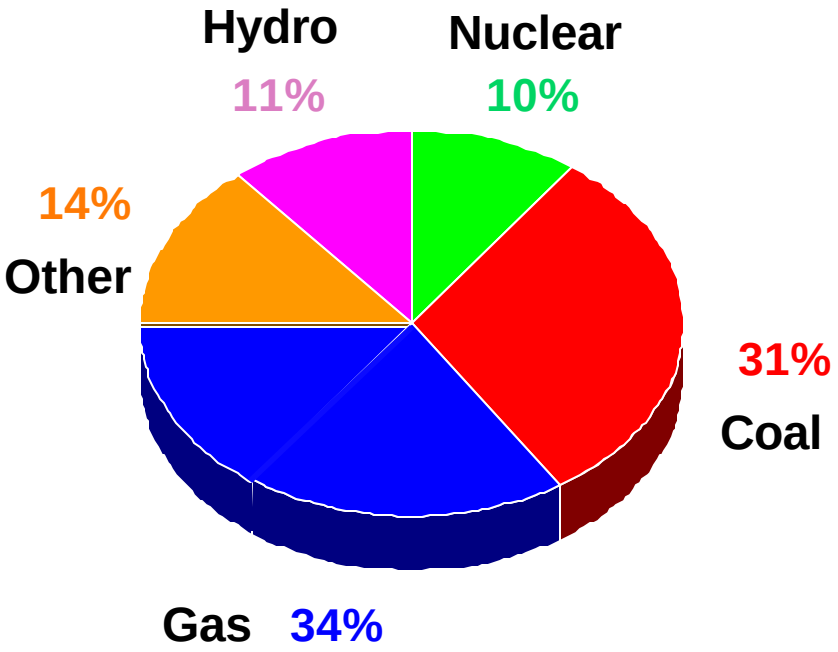
Outline

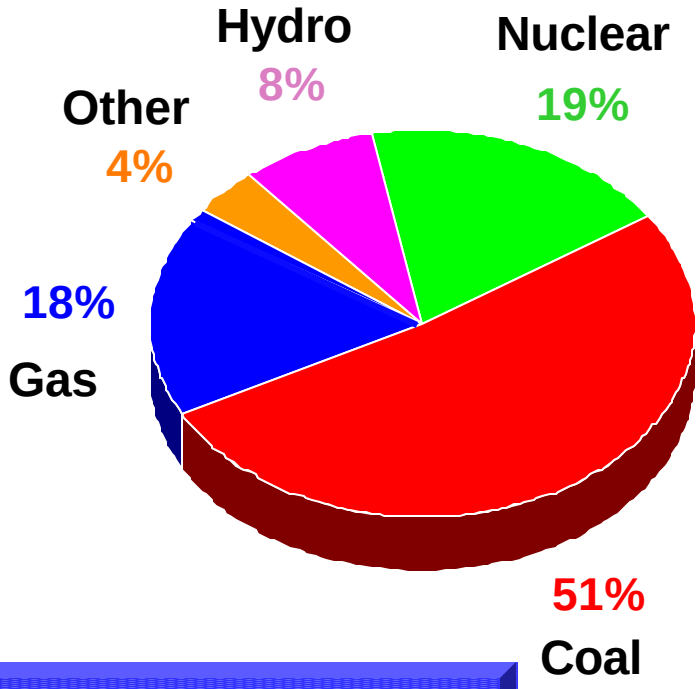
- **World Energy Landscape**
- **Renewable Energy and PV**
- **PV Industry and Markets**
- **GE Plans in PV**
- **GE Technology Developments in PV**
- **Long term vision**

Where Are We Today?

Installed Capacity

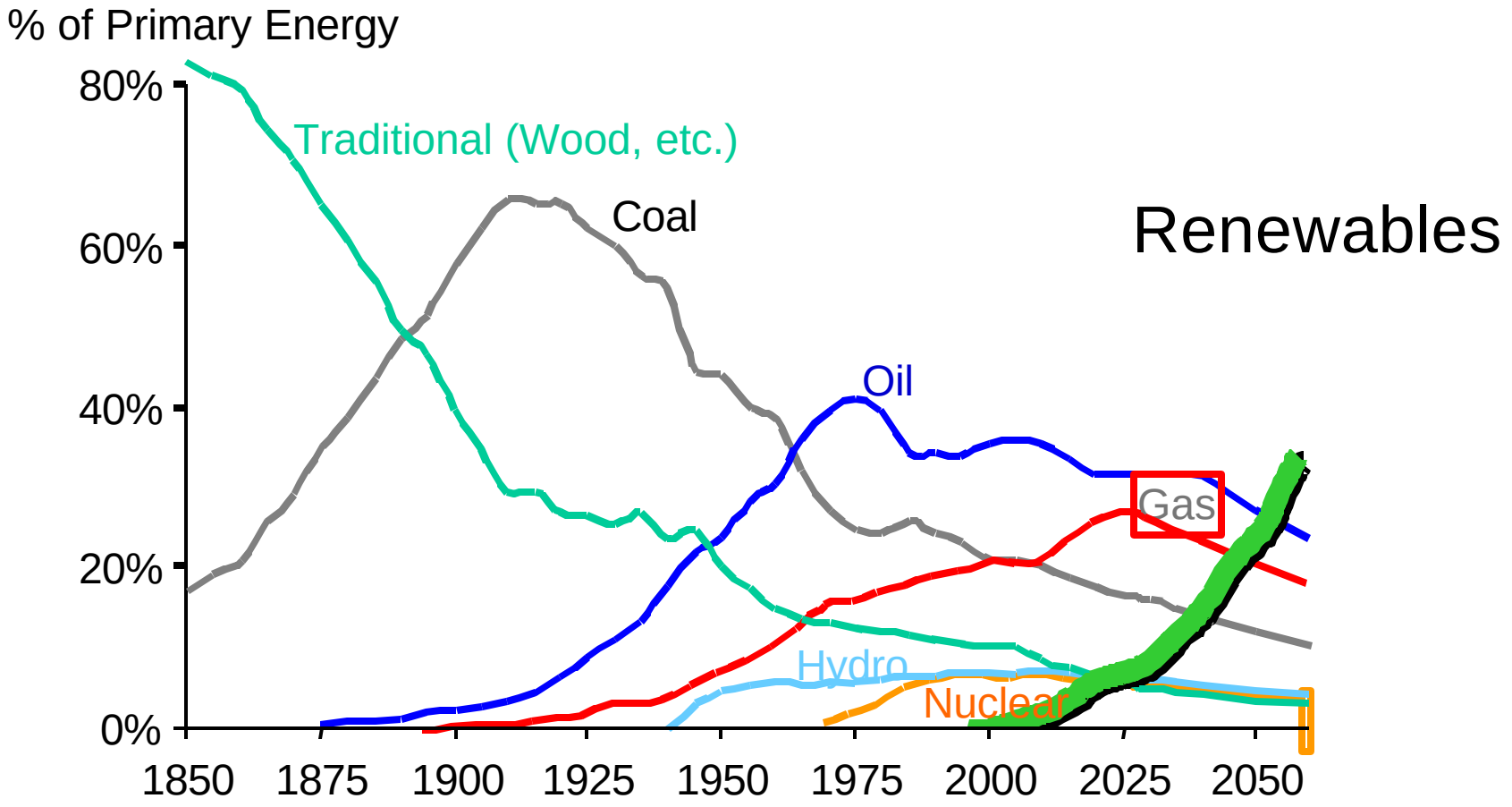


Energy



Nuclear, Gas and Coal Predominate

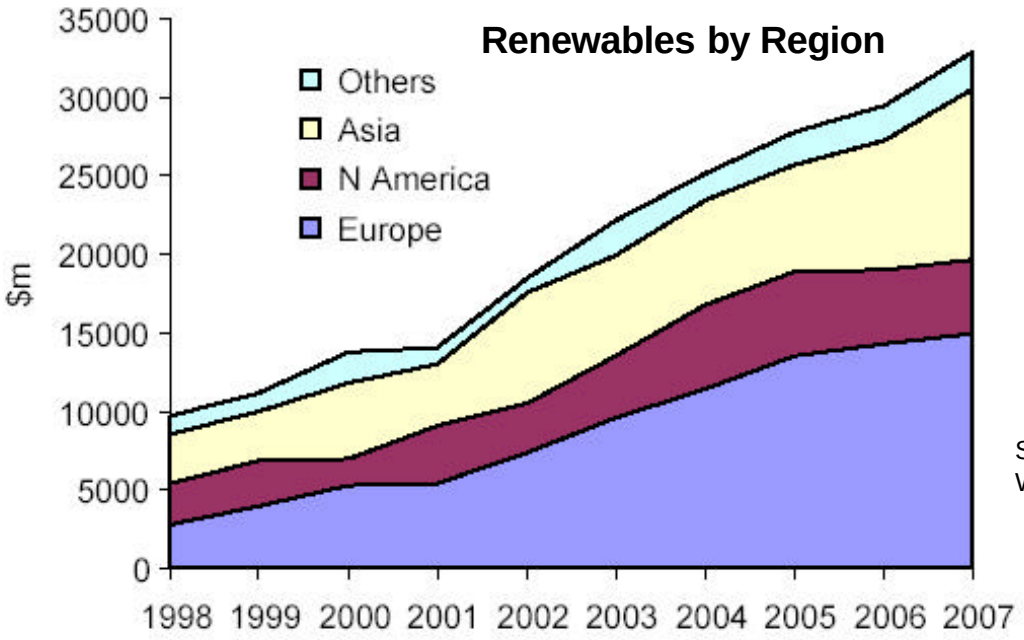
Where Are We Going?

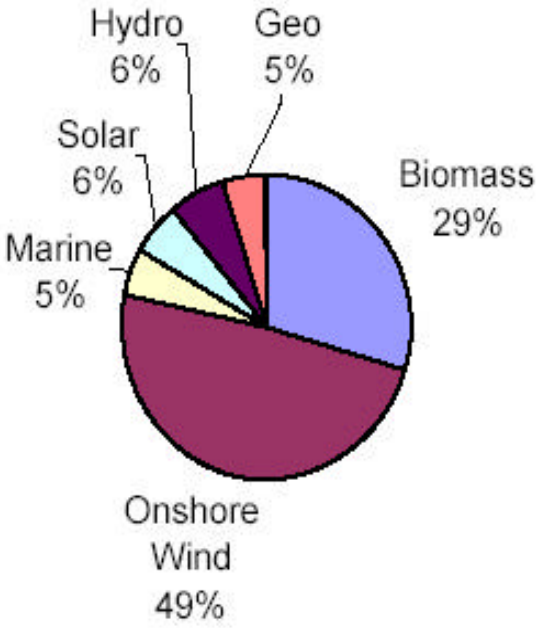


Source: Shell Global Scenarios

Renewable Growth

- **Onshore Wind**
- **Biomass**
- **Hydro-Electric**
- **Solar**
- **Geothermal**
- **Marine (Wind, Wave, Tidal, Current)**

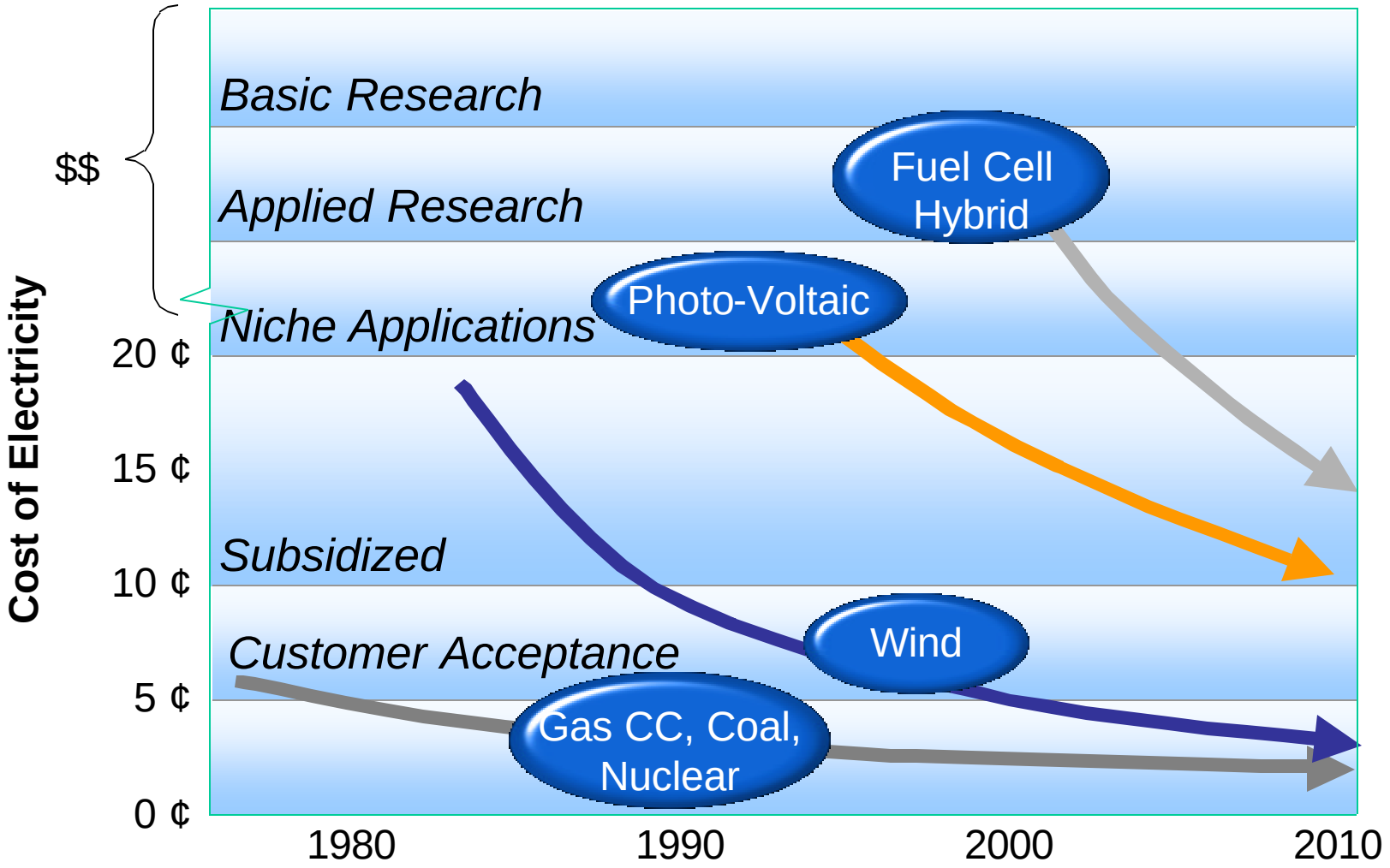




Global Renewables 2003-2007
Combined Capex Growth 30% p.a.

Source: Douglas-Westwood 2003

Cost of Electricity



CoE Competitive with Conventional Energy Sources

PV Status

Market

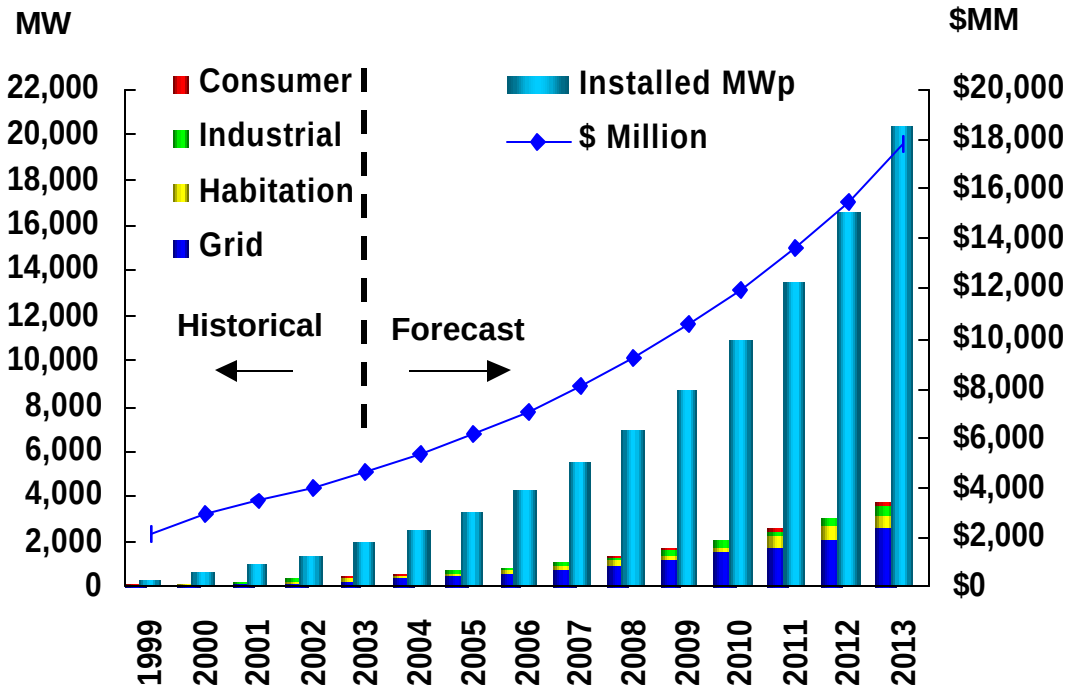
- Transitioning from Niche to Mainstream
- $4-5B Industry, Following Wind Growth
- 20+% CAGR in MW
- PV Competes w/ Retail Electricity

Technology

- COE 25¢/kWh, 10¢ by 2010
- Silicon Efficiency ~15%,
- Growing to 20% with technology

Challenges

- Large Scale Production
- Cost & Availability of Si
- Integrated Residential, Commercial, Grid



50% Grid, 20% Off-Grid Homes, 12% Off-Grid Industrial

Current Environment – PV Industry

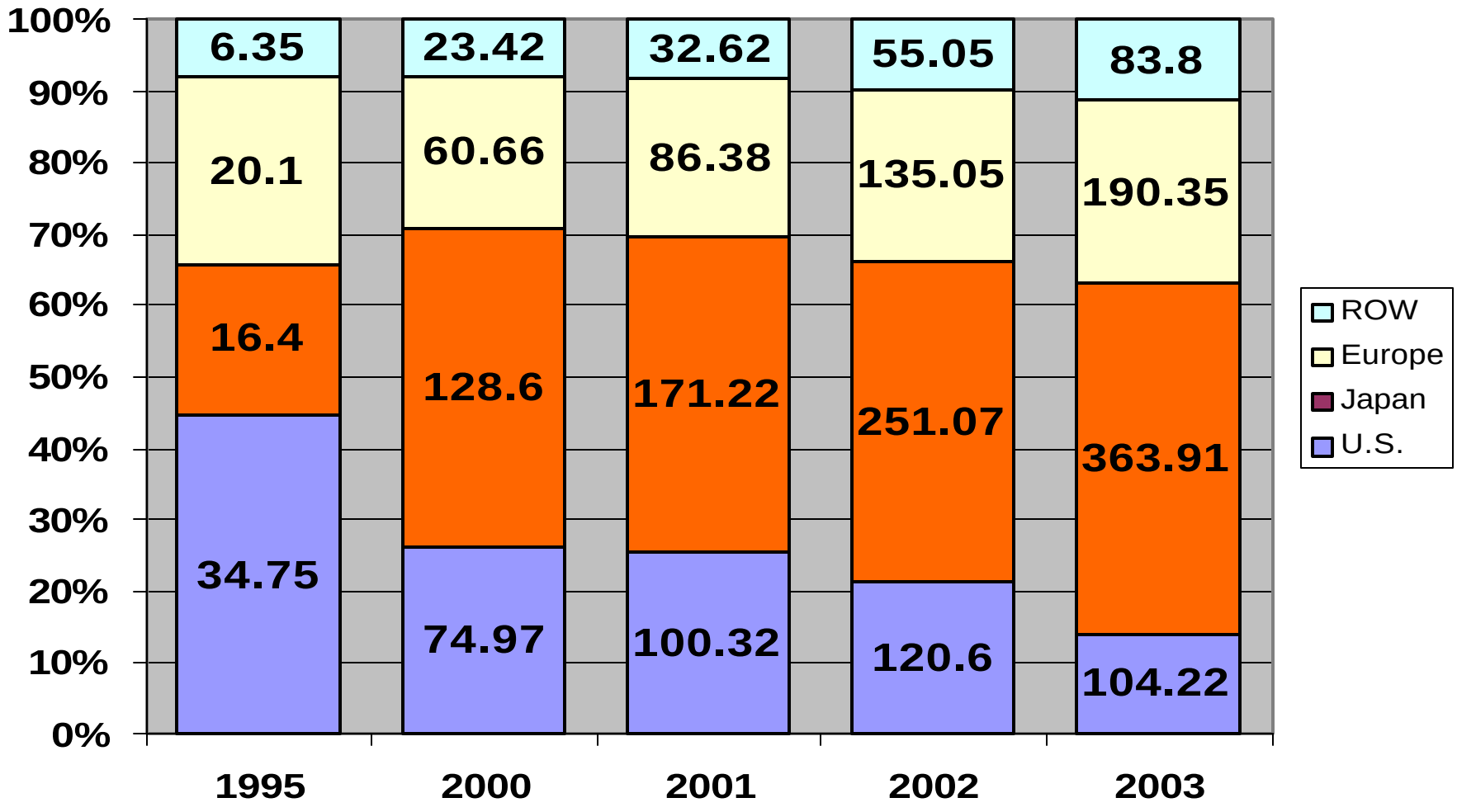
Today's market

- **Demand now exceeds capacity !**
  - **Wafer and solar cell vendors are sold out**
  - **Solar cells unavailable or only available at very high prices**
- **Supply of solar grade silicon cannot meet demand**
  - **Price increase from ~ $28/kg to ~ $35/kg in last year**

Technology Response

- **Lowered silicon wafering cost**
  - **thinner wafers**
  - **lower cutting losses and higher yield**
- **Higher efficiency solar cells (more W per wafer)**
  - **better silicon utilization**
  - **hetero- junction**
- **Alternative Approaches**
  - **thin film**
  - **Si Film**
  - **CIS and other non- Si**

PV World Summary



World Production is Expanding- Europe and Japan Leading

PV Market Summary

Grid Connected	Off-Grid Habitation
’03: $3150MM	’03: $670MM
51%	19%
• Residential Buildings • Commercial/ Industrial Buildings • Central/Substations	• Village Power for Schools, Clinics, Mini Grids • Vacation / Off-grid Homes • Water Pumping/ Irrigation • Desalination/Water Treatment
 	
• Requires inverters to convert DC to AC • Key opportunities are in Developed Countries	• Typically requires energy storage • Key opportunities are in Developing Countries (e.g. India) - minigrid system

U.S. Market Application Summary

Application	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*
Grid-connected Distributed	2.2	3.7	5.5	12.0	22.0	32	
Off-Grid Consumer	4.5	5.5	6.0	7.0	8.4	9.0	
Government Projects	1.5	2.5	2.5	1.0	1.0	1.0	
Off-grid Industrial /Commercial	5.2	6.5	7.5	9.0	13.0	16.0	
Consumer (< 40 watts)	2.4	2.4	2.5	3.0	4.0	4.0	
Central Station	-	-	-	-	-	5.0	
Total U.S. Installed	**15.8**	**21.0**	**24.0**	**32.0**	**48.4**	**67**	
IMPORTS		**2.0**	**4.0**	**5.0**	**9.0**	**18.0**	
EXPORTS	**37.9**	**39.8**	**55.0**	**73.3**	**81.2**	**54.0**	
TOTAL PRODUCED	**53.7**	**60.8**	**75.0**	**100.3**	**120.6**	**103**	

Market Drivers Grid Distributed PV

U.S.
- Buy-down incentives
- Energy cost hedge

Europe
- High feed in tariff (FIT)
- Green energy

Japan
- High cost of energy
- Green energy

Customer CTQ’s Grid Distributed PV

Residential
- Low cost
- Building Integrated
- System
- High reliability (25 years)

Commercial
- Low cost (short payback)
- High reliability (30 years)
- System

PV Industry Summary

Current Industry Leaders

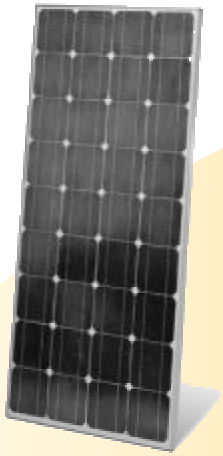
- BP Solar(E/US): c-Si, p-Si
- Evergreen (US): ribbon-Si
- GE Solar (US): c-Si, Si film
- Isophoton (E): c-Si
- Kyocera (J): p-Si
- Mitsubishi (J): c-Si, p-Si
- Photowatt (E): c-Si
- Q-Cell (E): p-Si
- RWE (E/US): c-Si, ribbon-Si
- Sanyo (J): c-Si/a-Si, a-Si
- Sharp (J): c-Si, p-Si
- Shell Solar (E/US): c-Si, CIS
- Solarworld (E): p-Si
- Sunways (E): p-Si
- United Solar (US): a-Si

Innovative Small Players

- Unisolar (US)
- Matrix (Canada)
- Konarka (US)
- Sunpower (US)

GE Plans in PV Industry

2004-2005



Improve What We Acquired

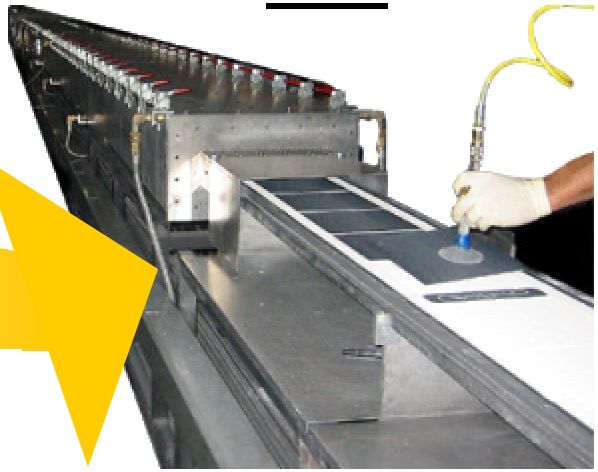
AstroPower Assets

2006-2007

Residential and Commercial Building-integrated PV Systems

Aesthetics and Growth

2010



Affordable PV

COE < 10 ¢/kWh

What GE Brings …

- **System Engineering**
- **Polymer Materials**
- **Electronics**
- **Advanced Technology: Global Research Center**
- **Six Sigma**
- **Brand**

GE- Government Technology Development

NIST ATP

New Solar Grade Silicon Feeding Silicon-Film Producti
$15 per kg feedstock
Joint program with Dow Corning

Si film Production Line

Sandia-DOE Inverter Program

Low Cost
High Reliability
High Efficiency
Meet IEEE 1547 grid connect standard
Transformer-less design
No fan
Dual string operation
GE Plans to Offer a full suite of PV products

New 3.5 KW PV Inverter

Long Term Vision

If you look at the heart of the industrial side of GE, we are the world's preeminent infrastructure company. And much of our stuff takes place over relatively long cycles. We've been in the energy for 100 years. So, if we want to stay in it for another 100 years, we'd better have a pretty good understanding of what kind of technologies people could be using to generate electricity 30 to 40 years from now…it's always easier to sell the things you're selling today if you can also captivate customers with what the future brings. That's just a truism.

Jeff Immelt, CEO, General Electric, October 2003