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Power Electronic Opportunites in Photovoltaic Solar Power

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SunPower Corporation

APEC 2006

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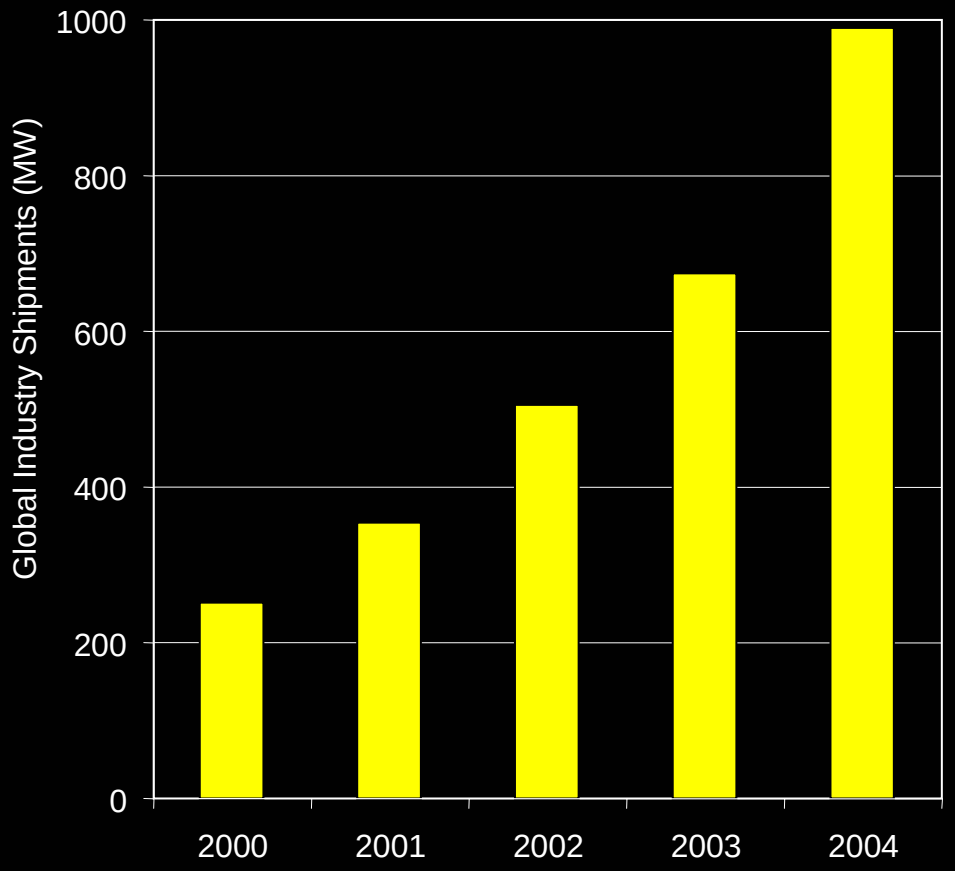
Outline

- PV Market Dynamics
  - Growing fast
- PV Economics
  - Costs are coming down
- Power Electronic Goals and Requirements

Global PV Market Status

- 2004 market grew 47%
- Growth during 4 of 5 past years > 40%
- Japanese and German success spurring others
- 1 GW/yr production by individual companies by 2010



Drivers of Solar Market Growth

- **Global Power Needs** — Roughly Double by 2025 - *US DOE*
- **Energy Prices** — Oil $50 - $110 per barrel - *Goldman Sachs*
- **Climate Change** — Need 30% Renewables by 2030 - *NREL*
- **Solar Price Parity** — 5 - 10 yrs for Major Markets - *SunPower*

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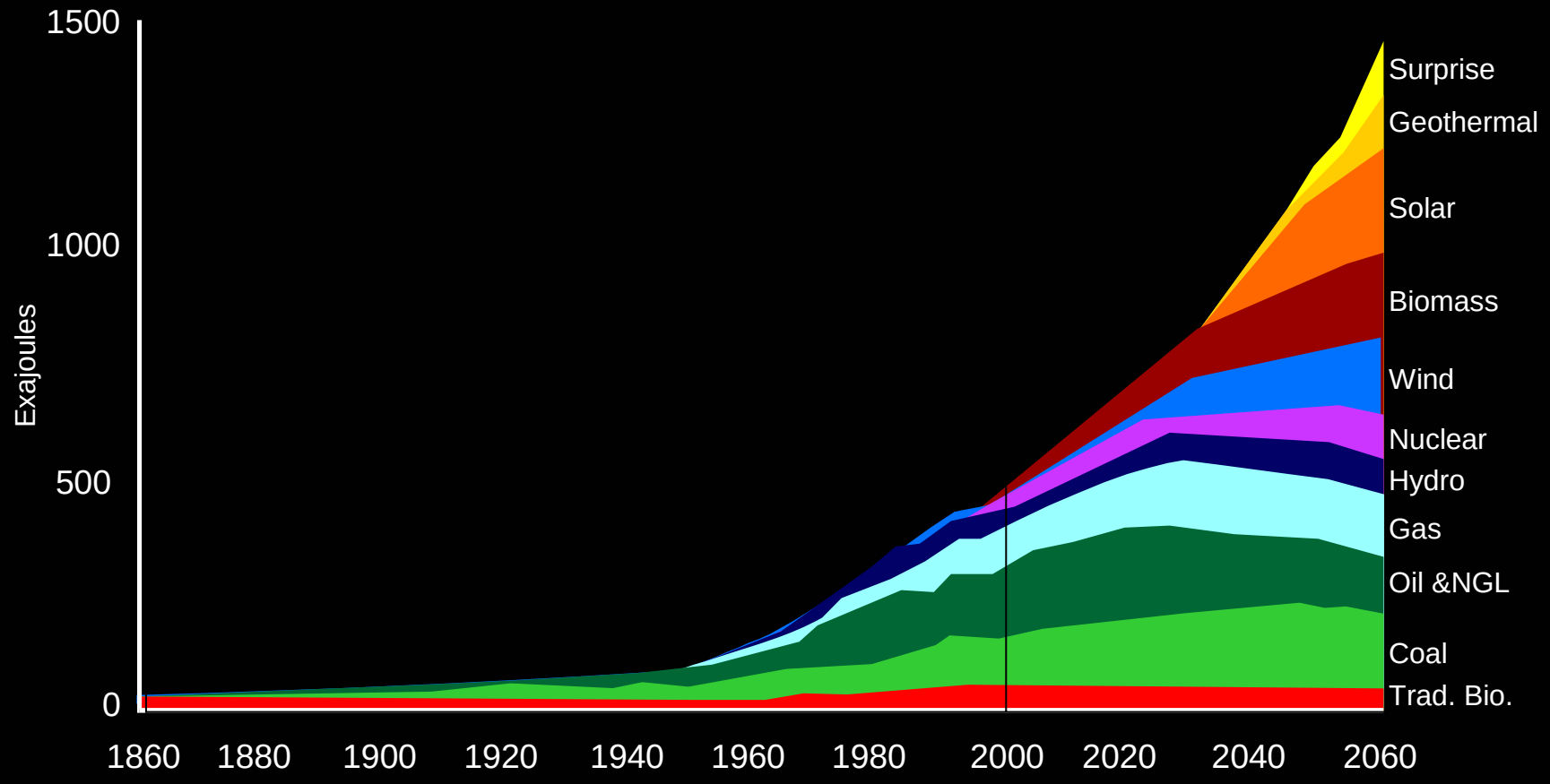
Shell Sustained Growth Scenario



Source: *Shell, The Evolution of the World's Energy Systems*, 1995

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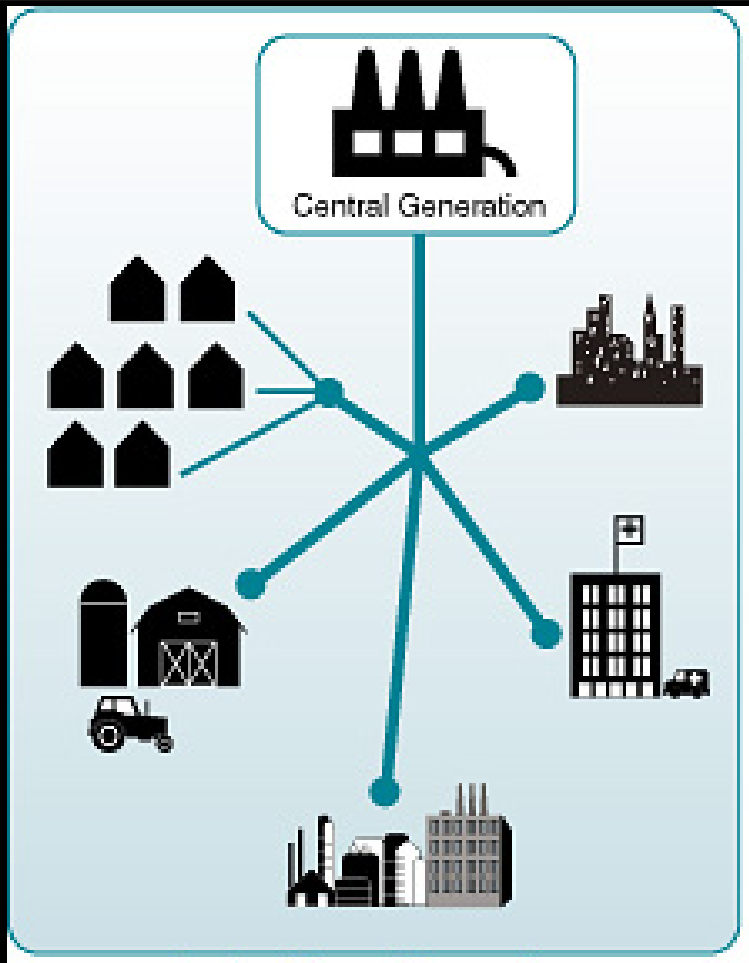
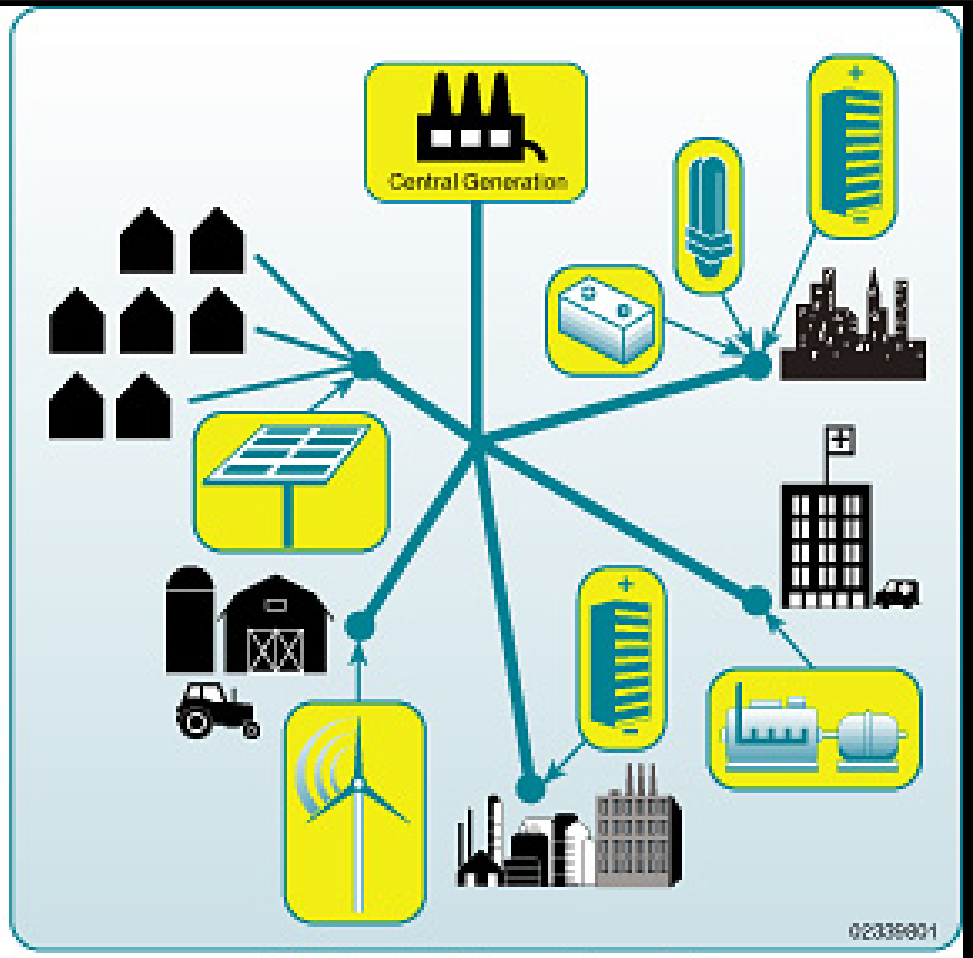
Distributed Generation Strategies are Shaping the Future



Central Power Generation



Distributed Power Generation

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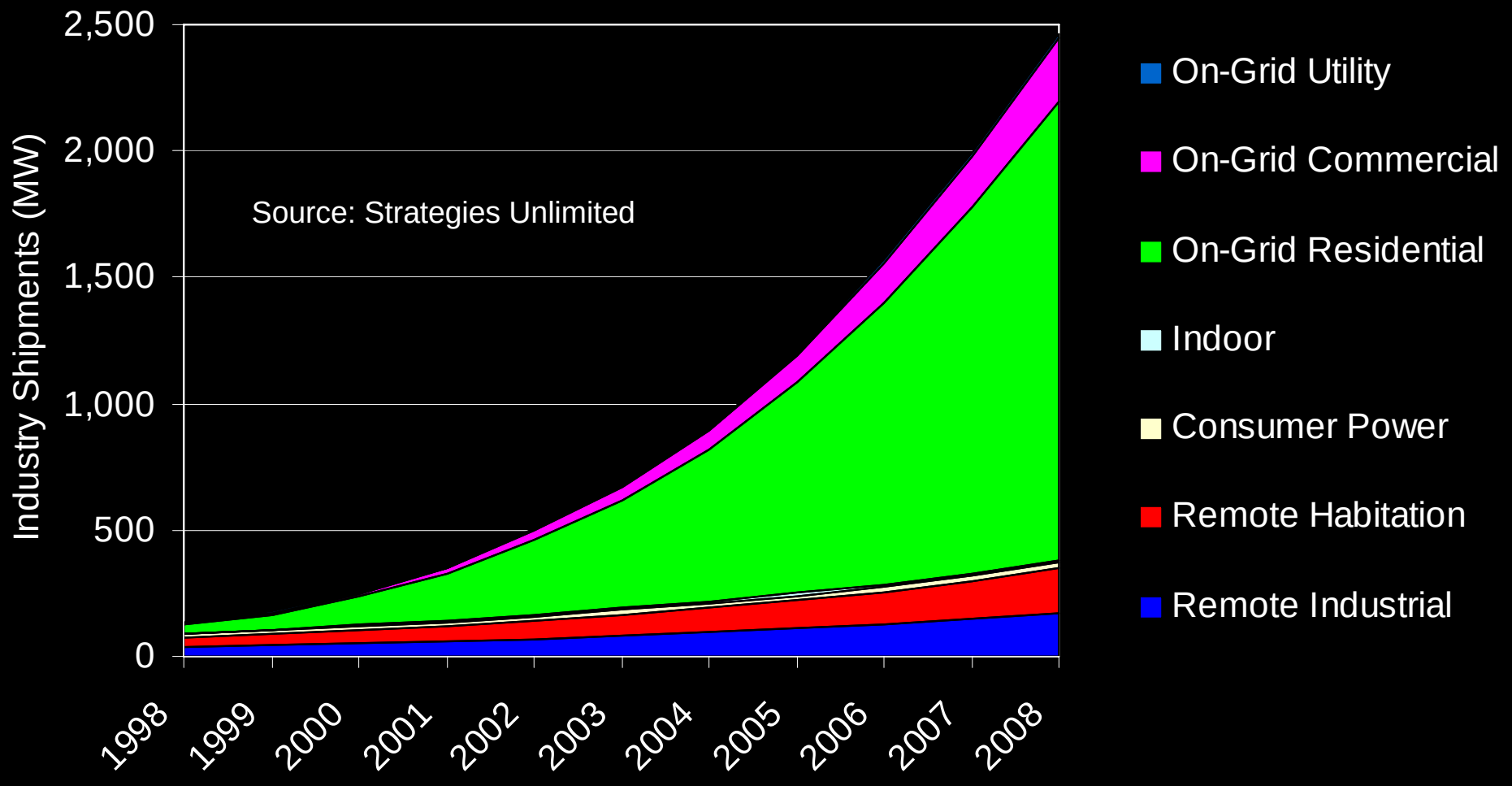
Market Growth



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Santa Barbara, California – 12.6 kW

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Walldürn, Germany – 8.0 kW

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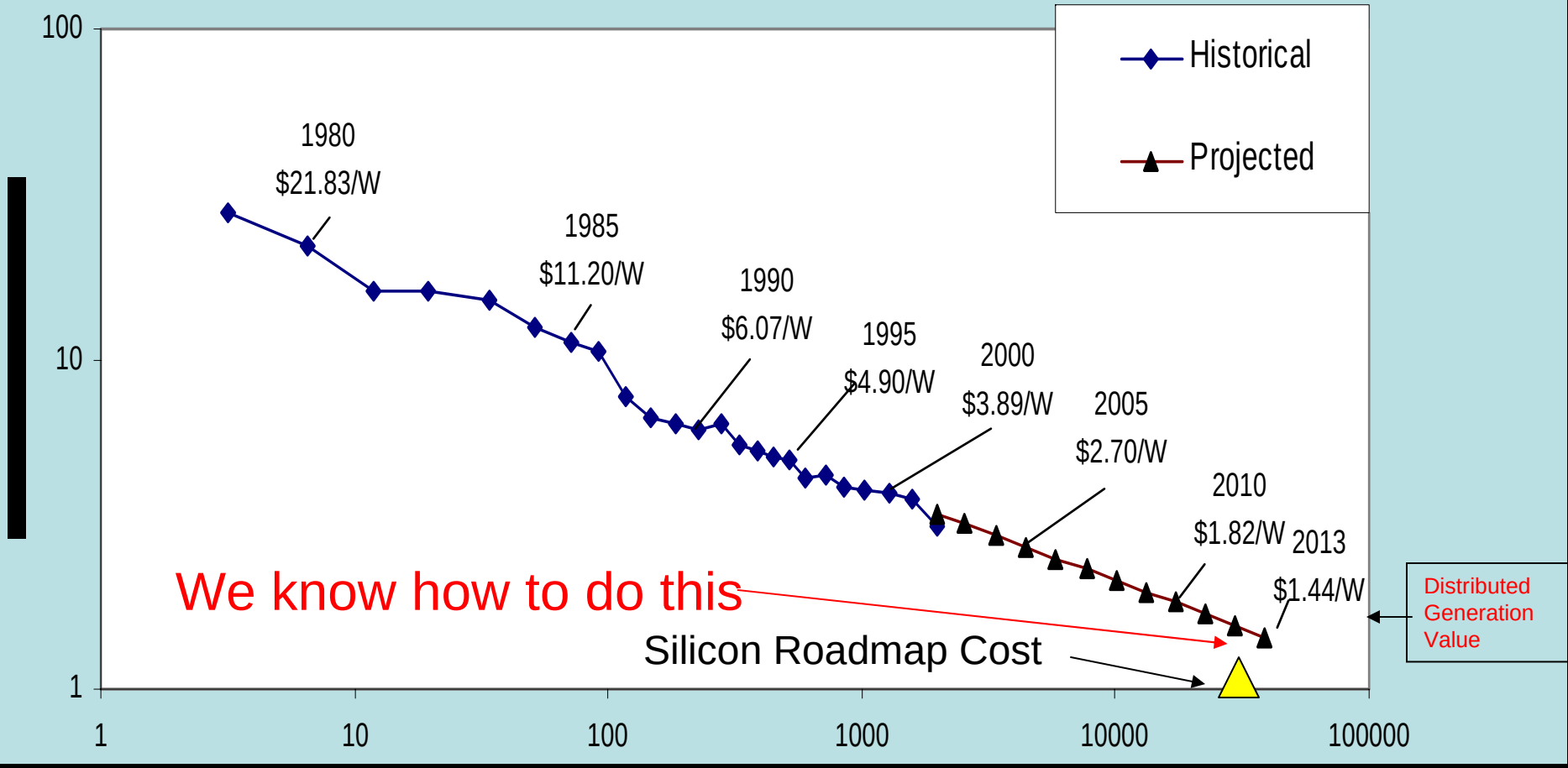
Osaka, Japan – 5 kW

In less than 10 Years, market incentives will not be needed



Inverter Topologies-Residential

- **Single Phase applications (<10kW) :**
  - o Non Isolated design – Boost section and inverter
  - o High Frequency galvanic isolation – High frequency transformation
  - o Low frequency isolation – single stage inverter with high efficiency transformer

- Main performance characteristics:
  - o Efficiency (>95%)
  - o High power density , low volume.
  - o High reliability
  - o High energy harvesting – single and multiple PV arrays, MPPT algorithms.
  - o Competitive cost
  - o Grid connectivity (islanding, UL)

Inverter Topologies-Commercial

- **Three Phase applications (> 50kW) :**
  - o Three phase, full bridge inverter.
  - o Tri-level inverter (experimental)
  - o Low or medium voltage transformer.

- Main performance characteristics:
  - o Efficiency (>97%)
  - o High power density , low volume.
  - o High reliability
  - o High energy harvesting – single and multiple PV arrays, MPPT algorithms.
  - o Competitive cost
  - o Grid connectivity.

Solar America Initiative (SAI)

A New Presidential Initiative from the Bush Administration

http://www1.eere.energy.gov/solar/solar_america/index.html

Purpose: Achieve the following aggressive cost goals in 2015 (Accelerating what was expected in 2020 by 5 years)

Residential: 8 – 10 ¢/kWhr

Commercial: 6 – 8 ¢/kWhr

Utility: 5 – 7 ¢/kWhr

Note: Corresponds to a 2 to 3-fold system cost reduction in 10 years. Can't be done without significant inverter improvements.

Solar America Initiative

- Approximately $50 million per year new R&D funding
- 5-10 Technology Pathway Partnerships
  - Vertically integrated groups working to gain value at intersections of the value chain

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Old DOE Roadmap

Now 2015

System Element	Units	2005	2011	2020
System Location		Phoenix		
Inverter Price	$/Wac	0.90	0.69	0.30
Inverter size	kW	4	4.74	5.92
DC-AC conversion efficiency	%	90	96	97
Inverter life/replacement	Years	5	10	20

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Technical Improvement Objectives

Technical Improvement Opportunities		Metrics			
TIER 1 TIOs	TIER 2 TIOs	Performance	Cost	O&M	Reliability
Modules	Module				
	Absorber				
	Cells and Contacts				
	Interconnects				
	Packaging				
	Manufacturing				
Inverters & BOS	Inverter				
	Inverter Software				
	Inverter Components/Design				
	Inverter Packaging/Manufacturing				
	Inverter Integration				
	Other BOS				
SE&I	Systems Engineering & Integration				
	Manufacturing/Assembly				
	Installation/Maintenance				
Deployment	Technology Acceptance				

RED indicates high-impact opportunities. YELLOW indicates moderate-impact opportunities.

Example Level-2 TIO Inverter Components/Design

- Incorporate emerging new componentry, such as room-temperature superconductors, silicon carbide switching devices, advanced magnetics, and longer-lived capacitors; advanced surge suppression; improved modeling and design optimization; and the development of fully integrated circuitry—new micro-chips to simplify designs, improve reliability, and reduce losses.

- Employ modeling, simulation, and prototype hardware development to completely redesign inverters for high-volume manufacturing with higher efficiencies and greater reliabilities. New algorithms for switching modulation, management of islanding, and interactions among parallel inverters for microgrid control will be developed and analyzed.