2.626 Fundamentals of Photovoltaics
Fall 2008

Background in Remaining Topics

Lecture 18 – 2.626

Tonio Buonassisi

Agenda

- 2.626 Status Review

Remaining Lectures At a Glance

11/11 Veteran's Day Holiday	11/13 Modules
11/18 Theory: Remaining Topics	11/20 Guest: Mike Rogol (Prices, Markets, Trends)
11/25 Guest: Brendan Neagle (Modules, Installations)	11/27 Thanksgiving Holiday
12/2 Tour: Evergreen Solar (10-11am)	12/4 Presentations Day 1
12/9 Presentations Day 2	

Agenda

Tour

- Evergreen signup sheet.
- Option: Additional Tours

Class Projects

- Class Budget: $400!
- Resources Check.
- Presentations Lottery.

Remaining Topics

Modules:

- Design criteria, tradeoffs, costs.
- Building integration, BIPV.
- System integration.
- Scaling, and integration into the power grid.
- Appropriate technology selection.
- Failure: failure modes in stationary and tracking systems, accelerated testing, field testing, service and warranty contracts.

Remaining Topics

Cost & Manufacturability:

- Cost: Building a cost model, key drivers of cost, substitution economics.
- Manufacturing: Environments, models, operations, process yield, handling.
- Predicting shortages and bottlenecks.
- Scaling: the multi-GW plant. Production technologies. Factory Tour.

Price and Markets:

- What sets price (and profit)
- Energy future and overview of renewable energy sources
- Economics and market dynamics
- Fluctuations in supply and demand, drivers for oversupply/undersupply conditions, and what this means for profits.
- Subsidies: Why subsidize? How much to subsidize? Role of PV in the global energy market.

Price, Markets & Subsidies

Markets

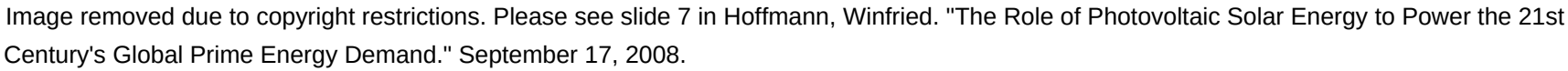
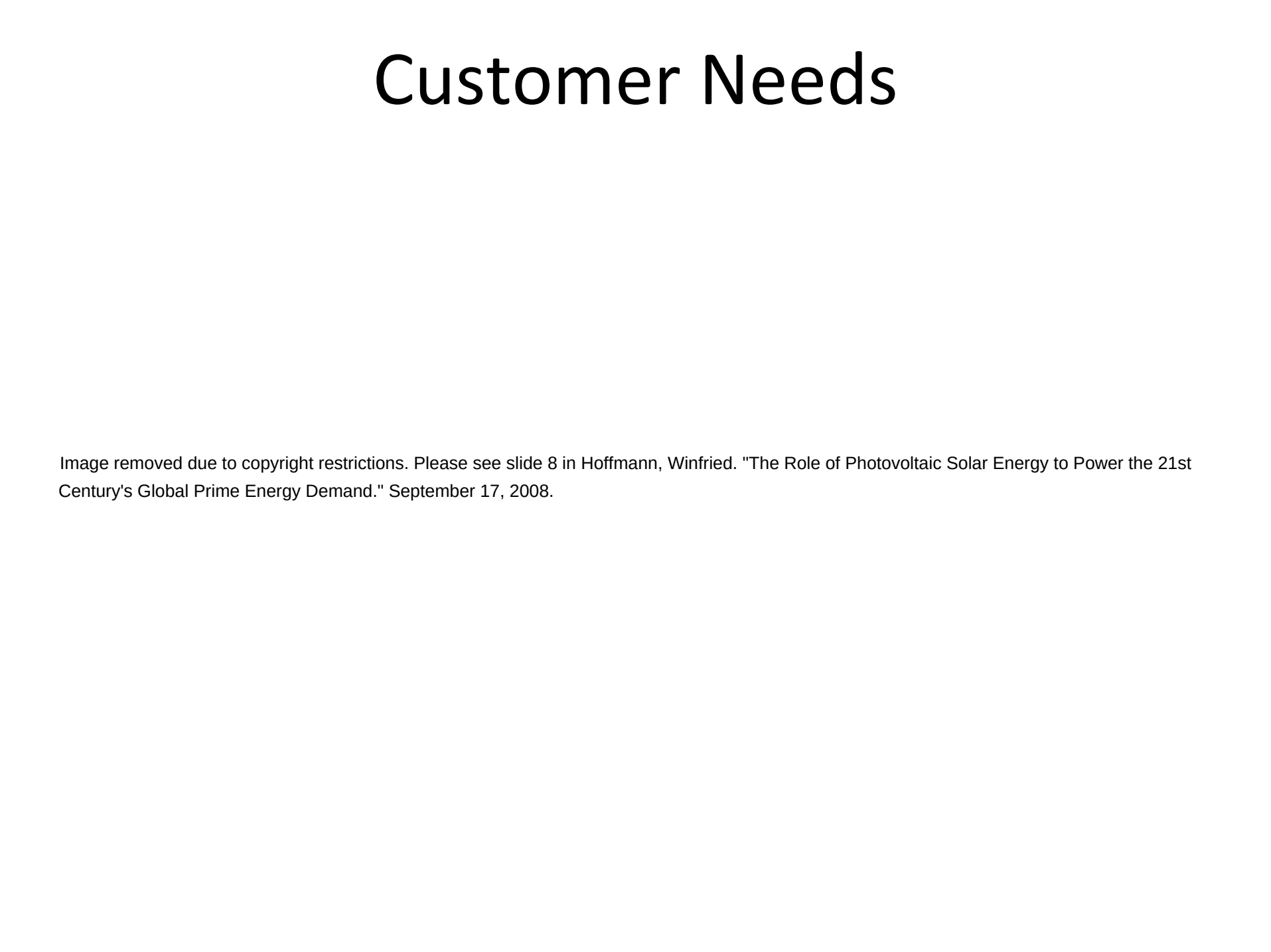


Image removed due to copyright restrictions. Please see slide 7 in Hoffmann, Winfried. "The Role of Photovoltaic Solar Energy to Power the 21st Century's Global Prime Energy Demand." September 17, 2008.

Customer Needs



Substitution Economics

- What type(s) of grid electricity will PV substitute?
  - What will this mean for traditional gencos?
- What is a fair selling price for PV electricity?

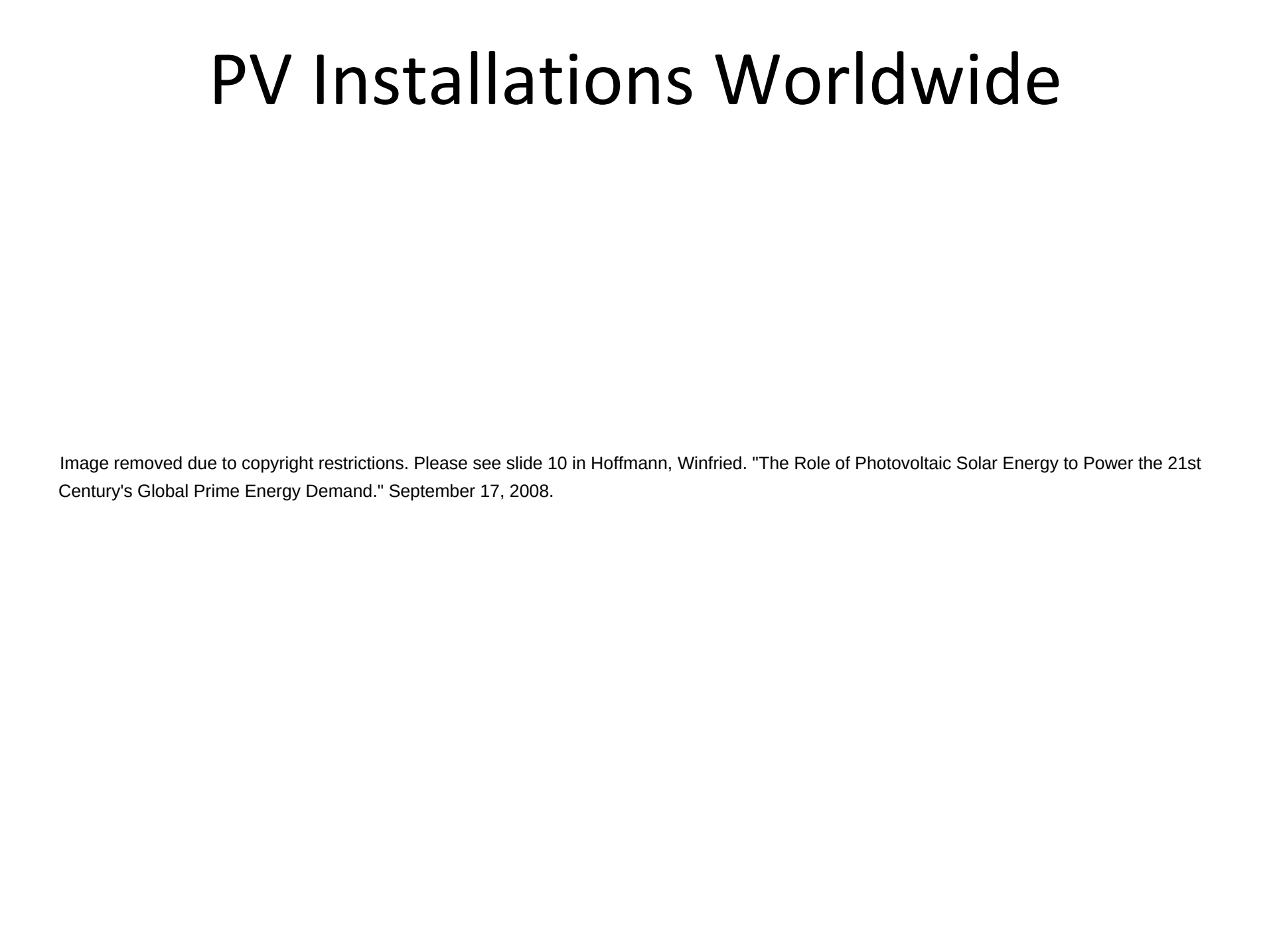
Markets


Image removed due to copyright restrictions. Please see slide 7 in Hoffmann, Winfried. "The Role of Photovoltaic Solar Energy to Power the 21st Century's Global Prime Energy Demand." September 17, 2008.

“Value” of PV Electricity

Image removed due to copyright restrictions. Please see slide 16 in Hoffmann, Winfried. "The Role of Photovoltaic Solar Energy to Power the 21st Century's Global Prime Energy Demand." September 17, 2008.

PV Installations Worldwide



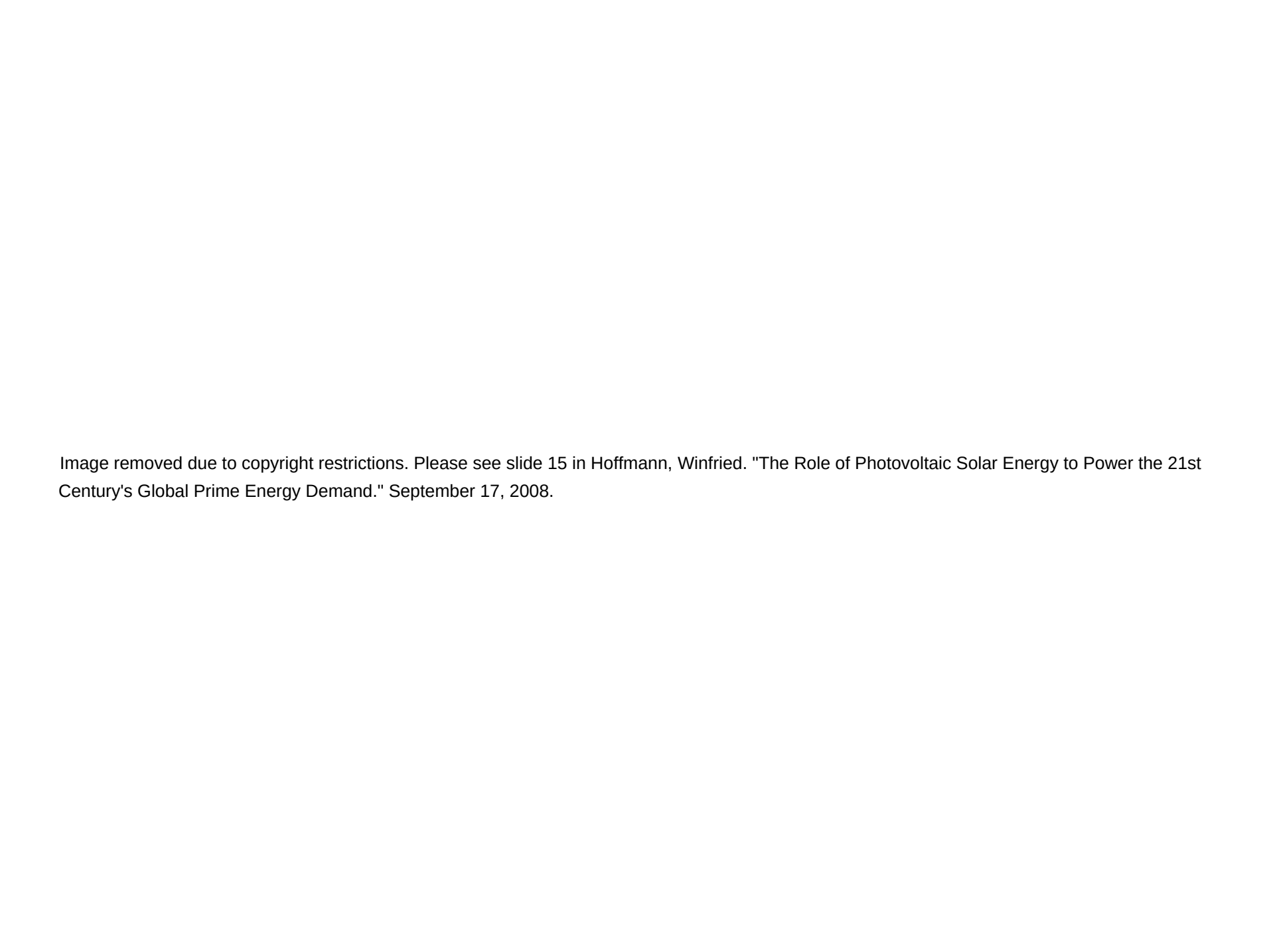


Image removed due to copyright restrictions. Please see slide 15 in Hoffmann, Winfried. "The Role of Photovoltaic Solar Energy to Power the 21st Century's Global Prime Energy Demand." September 17, 2008.

Seasonal and Diurnal Electricity Prices

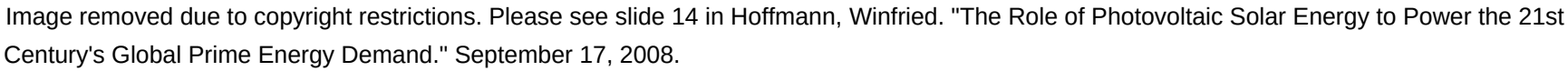
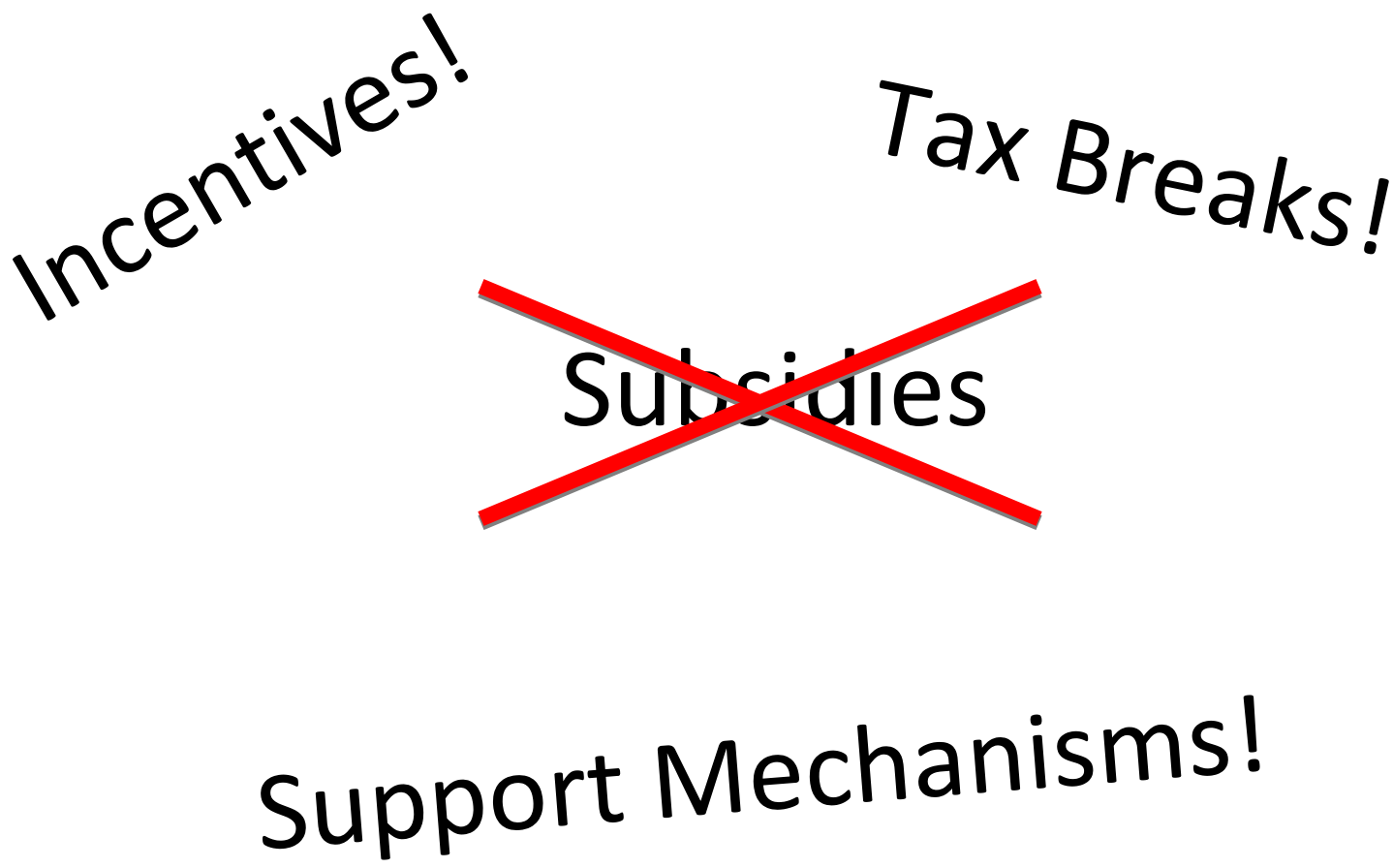


Image removed due to copyright restrictions. Please see slide 14 in Hoffmann, Winfried. "The Role of Photovoltaic Solar Energy to Power the 21st Century's Global Prime Energy Demand." September 17, 2008.

Image removed due to copyright restrictions.
Please see slide 11 in Hoffmann, Winfried. "The Role of Photovoltaic
Solar Energy to Power the 21st Century's Global Prime Energy Demand." September 17, 2008.


Incentives!
Tax Breaks!
Subsidies
Support Mechanisms!

Summary of Support Mechanisms

Many forms of support

"best" depends on other policy objectives

	Measure	Advantages	Disadvantages	Examples
Margin enhancement	Feed-in tariff	Stable revenues. Technology specific	Uneconomic deployment	Germany/Spain/USA
	Premium to fossil market	Greater transparency	Greater uncertainty on fossil price	UK
	Tax relief	Simple	Too easily changed by Government	USA
	Grants/soft loans	Simple	Allocation procedure	EU member states, USA
Penalties	Carbon caps	Transparent	Customers pay premium for all generation	European emissions trading
Mixture	Renewable Obligations	Transparent, market driven. Technology independent	Price uncertainty Technology independent	UK

Slide courtesy D. Kammen, UC Berkeley

Subsidy schemes of important European PV markets

Image removed due to copyright restrictions. Please see slide 12 in Hoffmann, Winfried. "The Role of Photovoltaic Solar Energy to Power the 21st Century's Global Prime Energy Demand." September 17, 2008.

United States

- Lack of federal leadership led to fractionalized energy policy.
  - Huge state-to-state variation.
  - Website compiling all state-specific information:

    http://www.dsireusa.org/

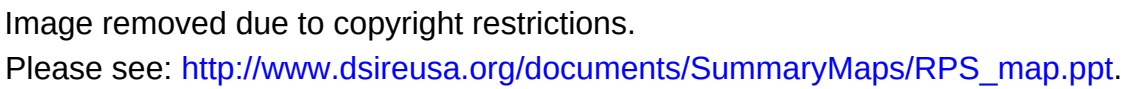


Image removed due to copyright restrictions.
Please see: http://www.dsireusa.org/documents/SummaryMaps/RPS_map.ppt.

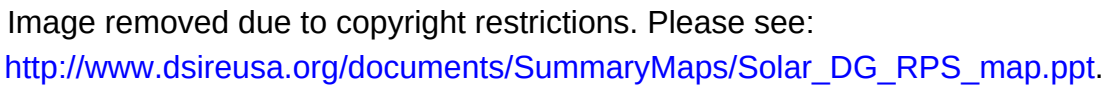


Image removed due to copyright restrictions. Please see:
http://www.dsireusa.org/documents/SummaryMaps/Solar_DG_RPS_map.ppt.

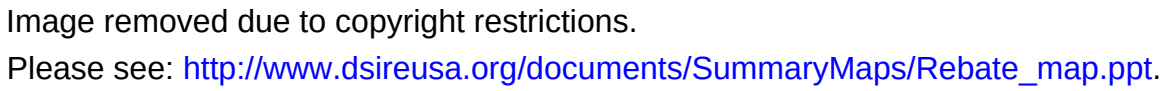
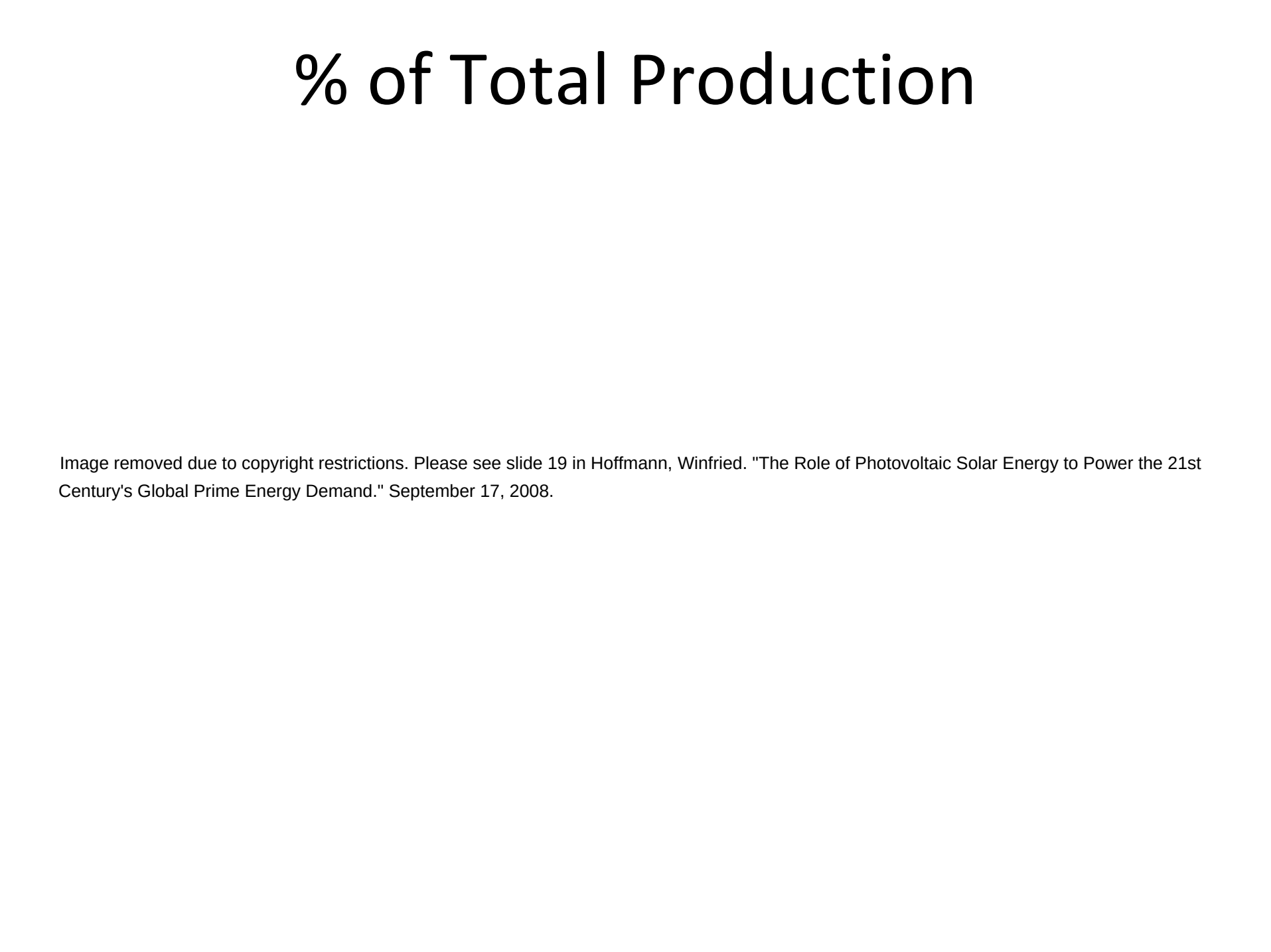


Image removed due to copyright restrictions.
Please see: http://www.dsireusa.org/documents/SummaryMaps/Rebate_map.ppt.

Projections


Image removed due to copyright restrictions. Please see Slide 8 in Hoffmann, Winfried. "Global Market Situation and Scenarios for the Next 5 Years." 2nd International Conference on *Solar Photovoltaic Investments*, February 19, 2008.

% of Total Production



Evolution of the Energy Mix

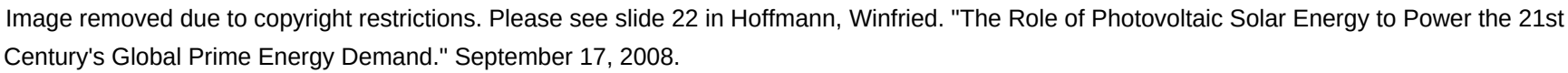


Image removed due to copyright restrictions. Please see slide 22 in Hoffmann, Winfried. "The Role of Photovoltaic Solar Energy to Power the 21st Century's Global Prime Energy Demand." September 17, 2008.

Technological Projections

Some “solutions” are radically different!

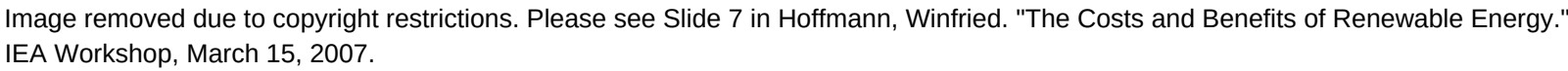


Image removed due to copyright restrictions. Please see Fig. 2b in Hoffert, Martin I., et al. “Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet.” *Science* 298 (November 1, 2002): 981-987.

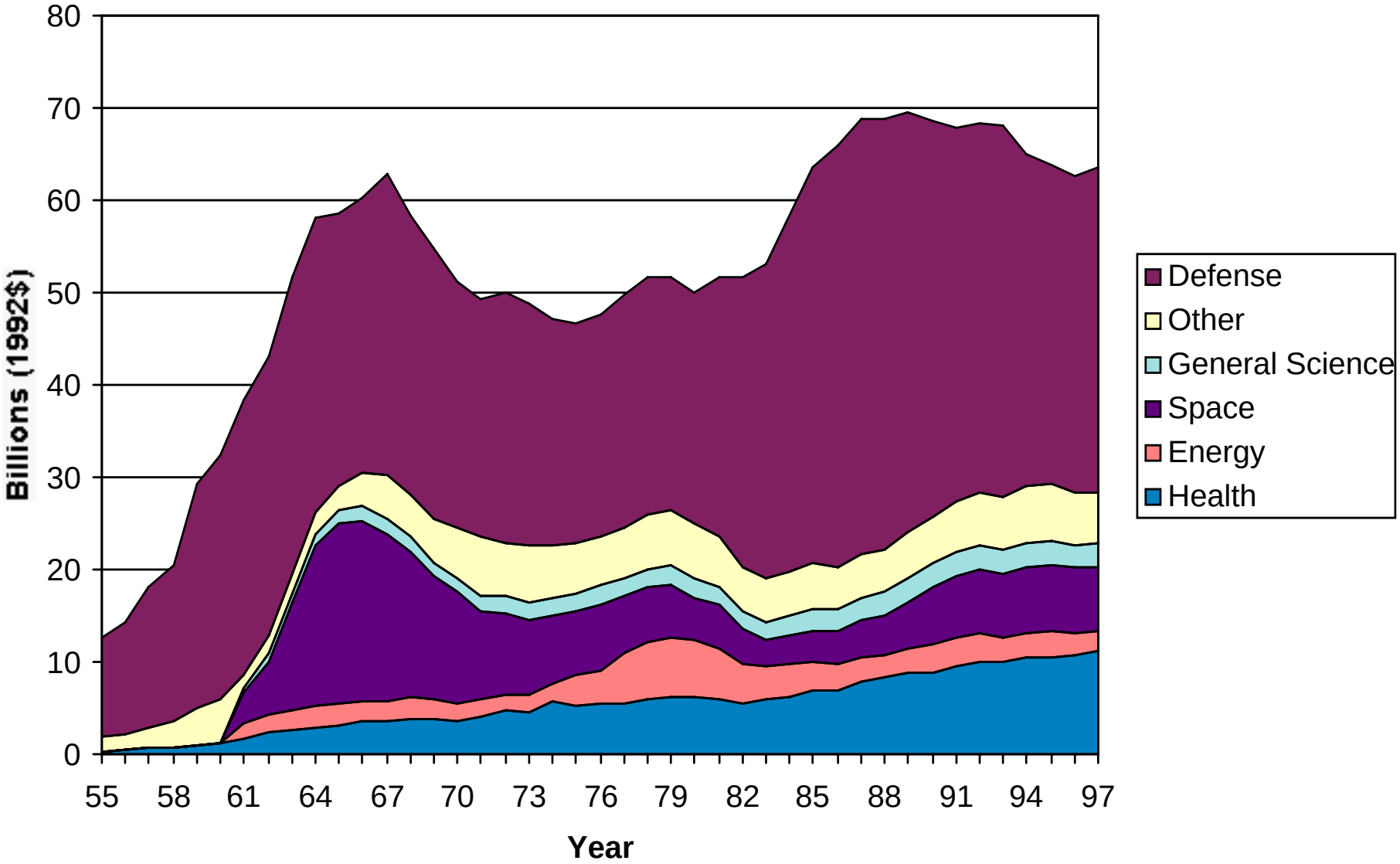
“Bucky” Fuller’s global electrical grid proposed in the 1970s augmented with computerized load management and high-temperature superconducting (HTS) cables could transmit electricity from day to night locations and foster low-loss distribution from remote, episodic or dangerous power sources. The resistivity of copper oxide HTS wires vanishes below the 77 K boiling point of

liquid N_2 available from air. ***Could HTS nanotubes do the job someday?***

Image removed due to copyright restrictions. Please see Fig. 3a in Hoffert, Martin I., et al. “Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet.” *Science* 298 (November 1, 2002): 981-987.

Investment & Technology Pipeline

U.S. Gov't R&D by Budget Function, 1955-199



Source: DOE, Clean Energy Futures (2000)

Trends in Nondefense R&D by Function, FY 1953-2004

outlays for the conduct of R&D, billions of constant FY 2003 dollars

Source: DOE, Clean Energy Futures (2000)

Image removed due to copyright restrictions. Please see http://www.aaas.org/spp/rd/histda04.pdf.

Funding-Patent Correlation for Energy

Patents Granted (thousands)

Image removed due to copyright restrictions. Please see Fig. 2b in Margolis, Robert M., and Daniel M. Kammen. "Underinvestment: The Energy Technology and R&D Policy Challenge." *Science* 285 (July 30, 1999): 690-692.

R&D Spending (billions)

R. Margolis and D. Kammen (1999) *Science*, 285, 690 - 692.

Funding-Patent Correlation for PV

Image removed due to copyright restrictions. Please see Fig. 2e, "Photovoltaics," in Kammen, Daniel M., and Gregory F. Nemet. "Reversing the Incredible Shrinking Energy R&D Budget." *Issues in Science and Technology* (Fall 2005): 84.

D. Kammen and G. Nemet, *Issues in Sci & Techn.*, Fall 2005, p. 84

Funding-Patent Correlation for Energy

Image removed due to copyright restrictions. Please see Fig. 2, "Patent data confirms problem," in Kammen, Daniel M., and Gregory F. Nemet. "Reversing the Incredible Shrinking Energy R&D Budget." *Issues in Science and Technology* (Fall 2005): 84.