Photovoltaic Power Generation

Military Energy Alternatives

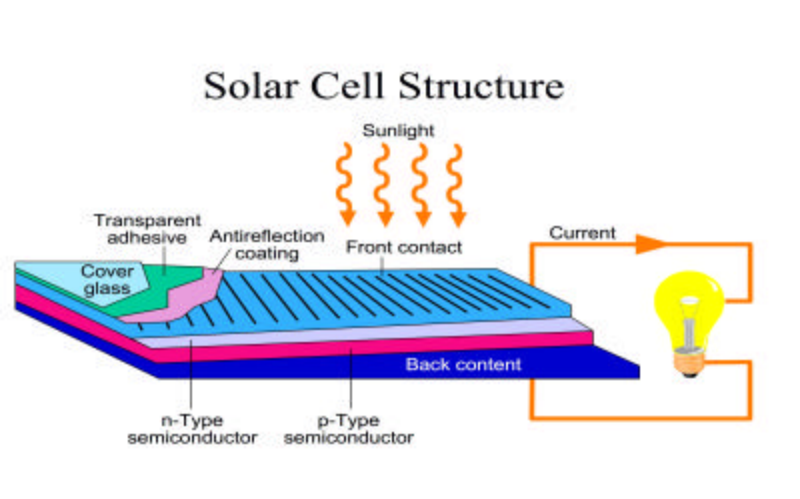
January 21, 2010

Elias (Lee) Stefanakos, PhD, PE
Director, Clean Energy Research Center
estefana@usf.edu http://cerc.eng.usf.edu

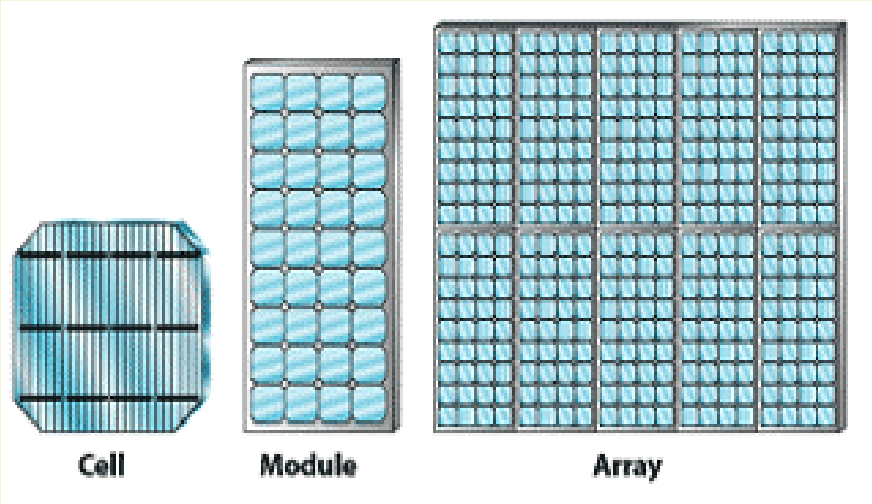
OUTLINE

- Photovoltaics (PV)
  - PV technologies
  - Performance
  - Cost
- New Concepts – Rectenna, Organic solar cells

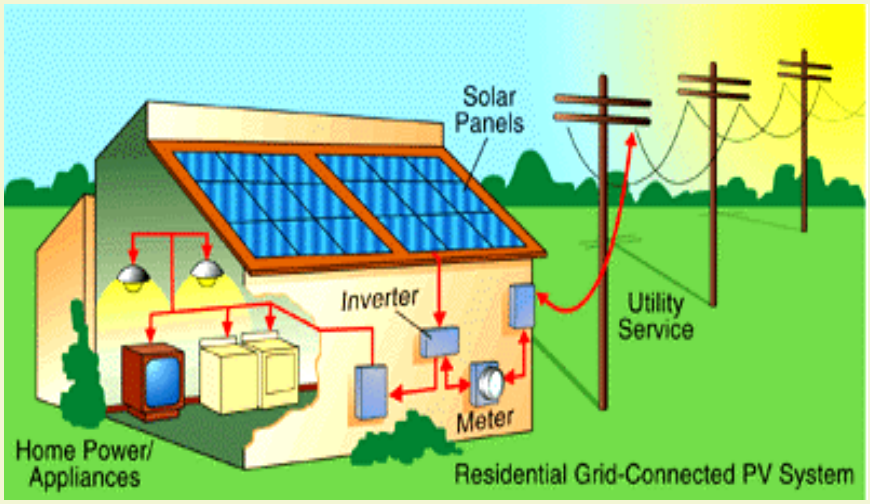
How a Solar Cell Works



PV Parts



Grid Connected System



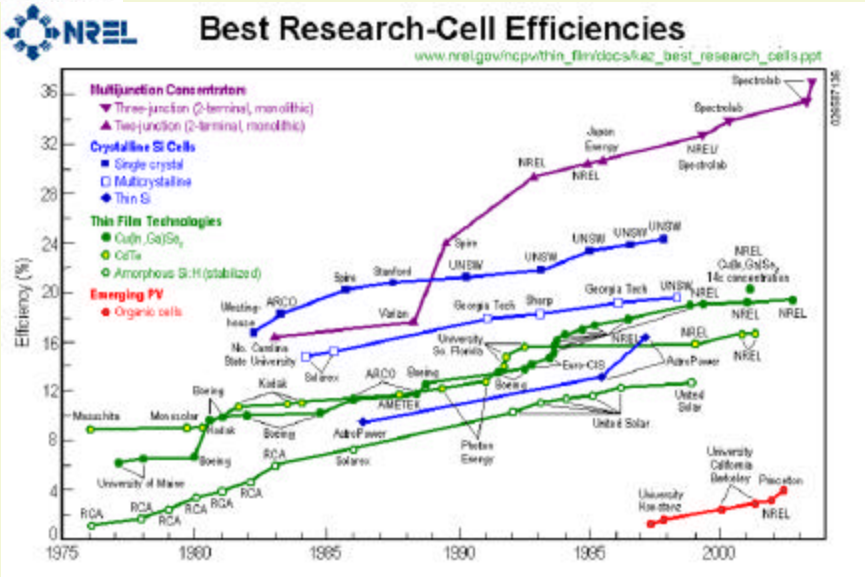
Dollars per watt

- **PV system cost typically in $/W**
- **If we assume 1000 W of sunlight incident on 1 m^2 of PV module**
- **If the sunlight-to-electric efficiency of the system is 10%, then 10% of that is output, or 100 W/m^2**
- **If the system costs $100/$m^2$, then the $/W cost is ($100/m^2) / (100 W/m^2) = $1/$W_p$.**

(1 m^2 ~ 10 ft^2)

Technologies

- Silicon
- III-V & Multijunction Solar Cells
- Concentrators
- Thin Films:
  - CdTe, $CuIn_{1-x}Ga_xSe_2$
  - a-Si



UNIVERSITY OF SOUTH FLORIDA

Electric Vehicle 20 kW PV Charging at CERC - USF

Georgia Tech 340 kW aquatic center entry pavilion

- III-V & Multijunction Solar Cells
- Concentrators

APS - Solar Test Center; 20 KW high-concentration system

University of Nevada Las Vegas – 15 KW Concentrator System

Large PV application - concentrator modules

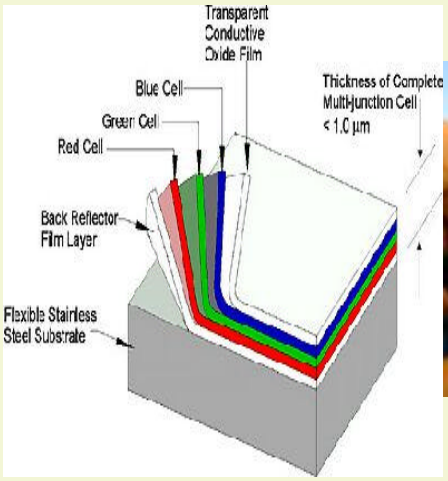
Thin Film Solar Cells

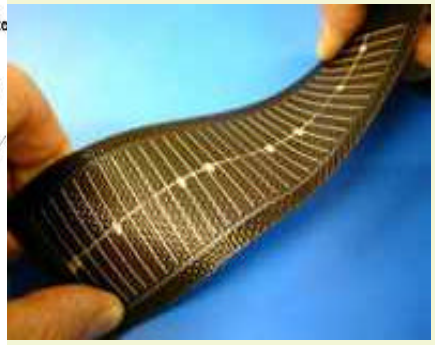
1. CuIn1-xGaxSe2 (CIGS)

2. CdTe (cadmium telluride)

3. a-Si (amorphous silicon)

Uni–Solar a-Si Thin Films





Cadmium Telluride (CdTe)

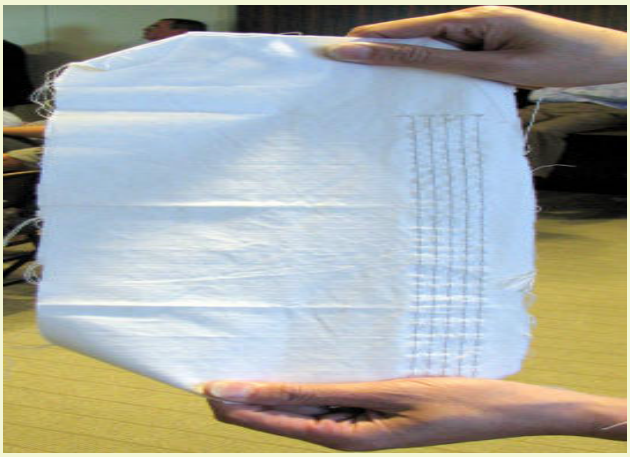
First Solar Advanced Thin-Film PV Modules at the Tucson Electric Power Array in Arizona.

Solar shade provides ~85% reduction in solar load
Power: ~1000W @ 12 VDC

Modular unit, equals ¼ of existing TEMPER tent

Power: ~190W @ 12 VDC

Solar power, woven into fabric.



Cost-Competitive Goals ($/$W_p$)

	Now: Rooftop	Now: Ground-mount	Future: Electricity Rooftop	Future: Electricity Ground	Future: Energy
Module	$2.5–3.5	$2.5 – 3.5	$0.4	$0.4	$0.15
Supports	$0.2	$0.4	$0.1	$0.1	$0.1
Wiring	$0.5	$0.5	$0.2	$0.15	$0.1
Power Condition	$0.8	$0.5	$0.25	$ 0.15	$0.05 (DC)
Design & Installation	$0.8 -1.8	$0.3 -0.5	$0.2	$ 0.1	$0.05
Land	0 (rooftop)	$0.02 ($4000/acre)	0	$ 0.03	$ 0.03
Miscellany	$0.3	$0.3	$ 0.05	$ 0.05	$0.02
Total	$5.3 - 7.3/$W_p$	$4.5-5.8/$W_p$	$1.2/$W_p$	**$1**/$W_p$	**$0.5**/$W_p$

MILITARY APPLICATIONS

Second generation solar technology

- Flexible & Light

1. Amorphous Silicon (Unisolar, Stainless steel foil)
2. CIGS (Daystar, titanium foil; Nanosolar,plastic; Global Solar, Stainless Steel)

- Standardized systems for on site installation

Rectenna

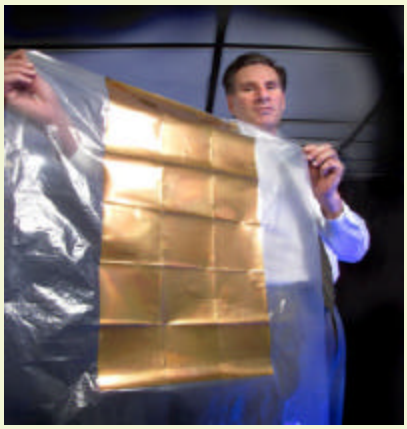
- Today, typical commercial Solar PV module efficiency is 10-20%
- Solar PV modules are inherently limited in efficiency
- Higher efficiencies in solar PV panels will be difficult to achieve due to physics and materials limitations
- 80-90% of solar energy is not utilized and escapes as excess heat in the form of radiation

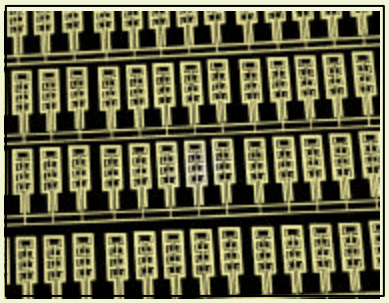
Fundamental New Approach

- Nanoscale Rectenna technology to convert thermal energy to electricity
  - Combining antennas & diodes
  - Concept of conversion is similar to a cell phone - at significantly higher frequencies
  - High conversion efficiency
- Manufacturing process leveraging standard lithography processes
- Utilizing low cost, non silicon materials

Product

30 THz Rectenna Array
Printed on flexible material





Cost Reductions

- Technology improvement (efficiency, design simplifications, process cost reductions)
- Higher volumes (less overhead, lower marketing and installation, bulk discounts)
- Manufacturing experience (process optimization, 'learning by doing')
- Product standardization and infrastructure development (installers, system designs)

CONCLUSIONS
PV

- Retail cost of present day PV modules is still high ($2-3/Wp). It needs to decrease to $1/Wp.
- Thin film and concentrator systems promise to reduce the cost.
- Additional R&D is needed in new concepts.