Solar Electricity: Working in Ohio

Sustainable Energy for Today's Business
NW Ohio Workshop March 22, 2007

Al Compaan
Distinguished University Professor of Physics

University of Toledo Clean and Alternative Energy Incubator
12 kW of First Solar panels at Dorr and Westwood with 6 kW used for H_2 generation

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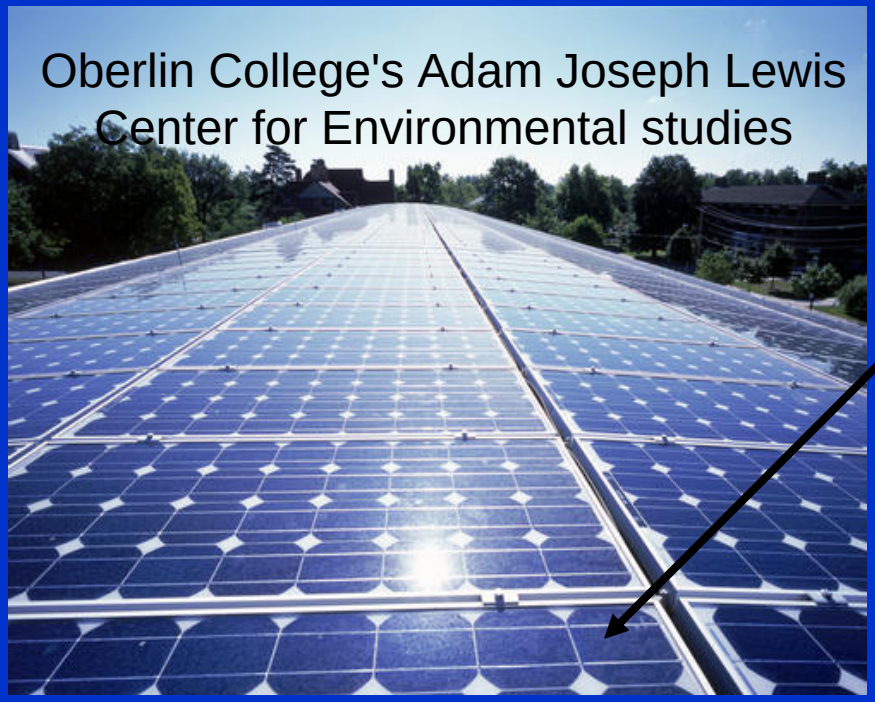
state-of-the technology of solar electricity

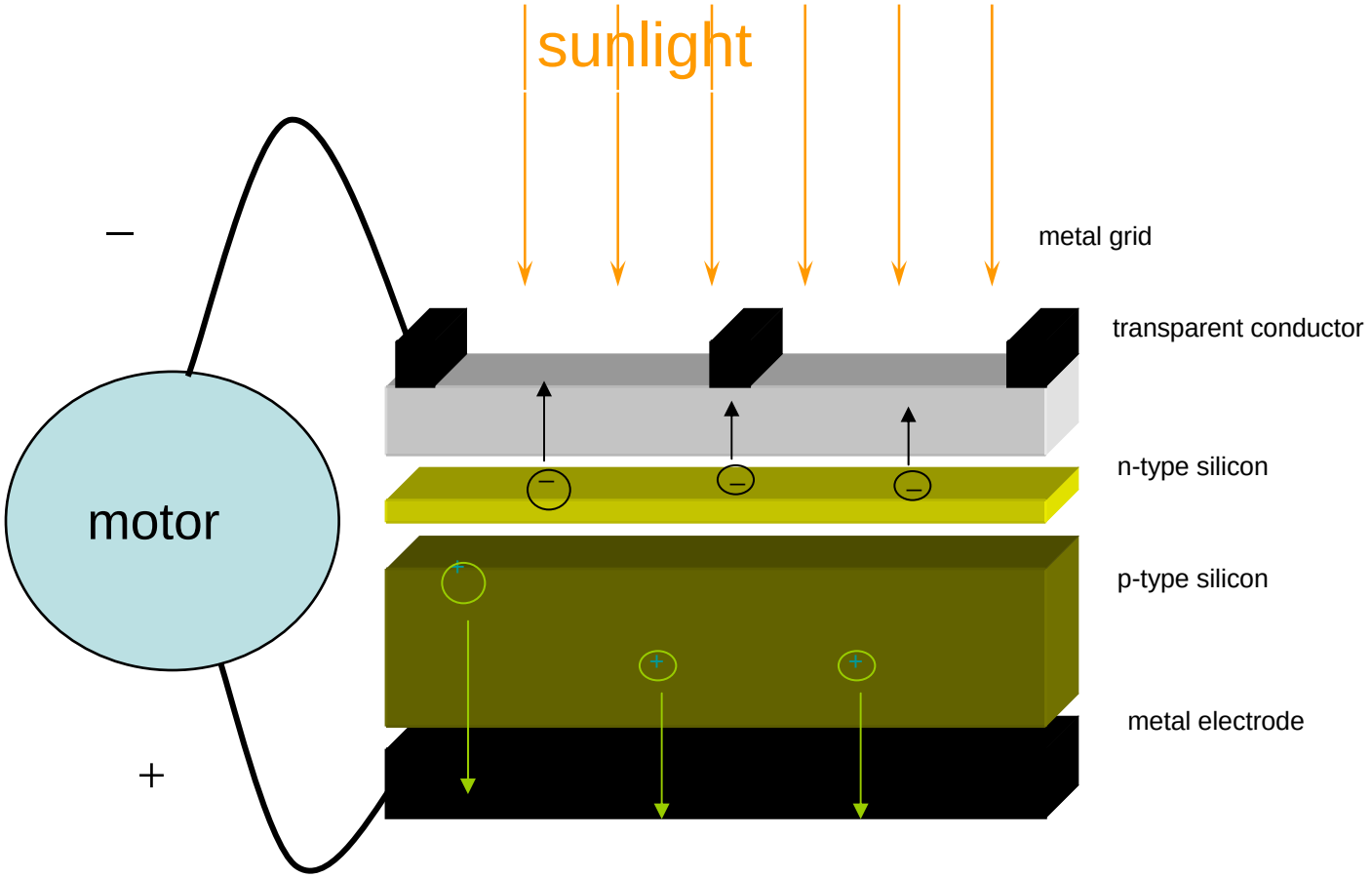


- panels made from silicon wafers assembled into modules...*versus*:

+ flexible shingles from a-Si...or

+ monolithically integrated glass modules with cadmium telluride film

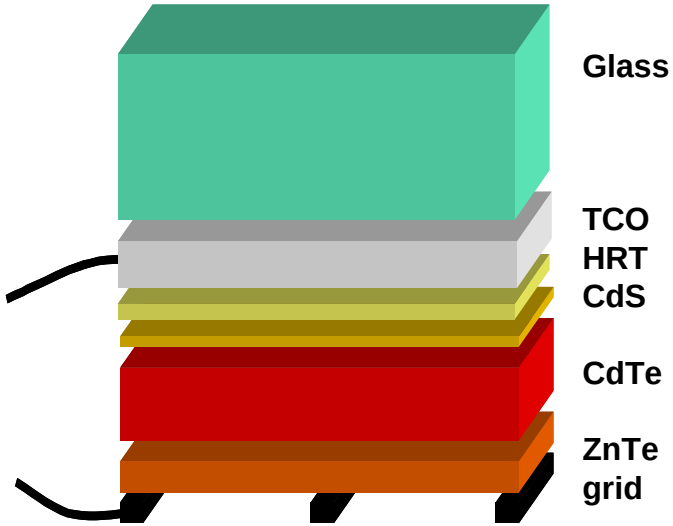
the traditional silicon solar cell



cadmium-telluride-based PV at UT

(Al Compaan, Rob Collins, Dean Giolando, Victor Karpov)

- solar cells on glass superstrates
- solar cells on polyimide substrates
- tandem, high efficiency cells



Typically the back contact is a metal or carbon paste rather than the transparent ZnTe shown here.

web page: http://www.cmse.utoledo.edu/photovoltaics.html

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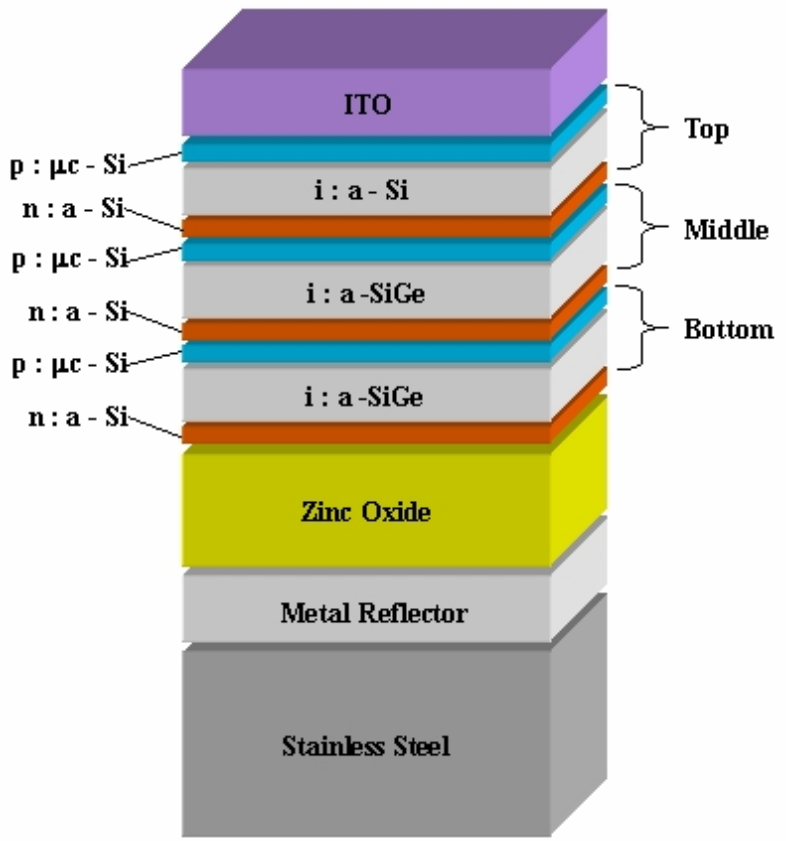
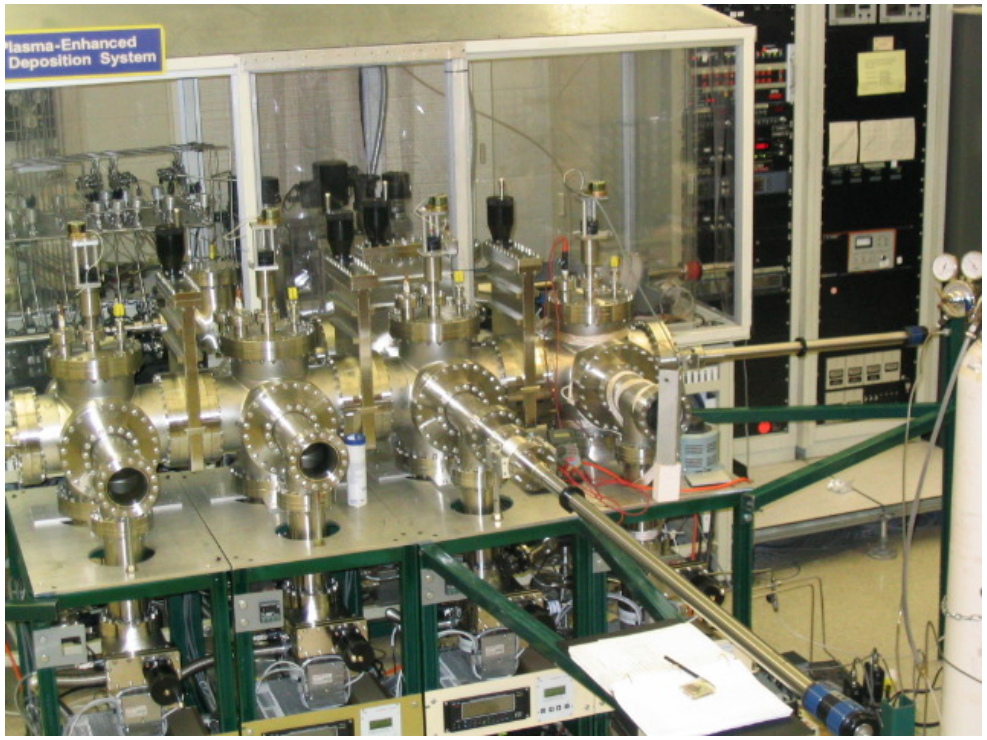
Amorphous Silicon-Based PV at UT

Triple-junction Structure



UT's PECVD device fabrication system



a new hot-filament chamber, and four new sputter deposition chambers have been added to support research funded by the AFRL

Solar cells on thin stainless steel

- High efficiency
- Lightweight
- Flexible
- Durable

For more information, please visit:
http://www.physics.utoledo.edu/~dengx/deng.htm

Xunming Deng, Rob Collins

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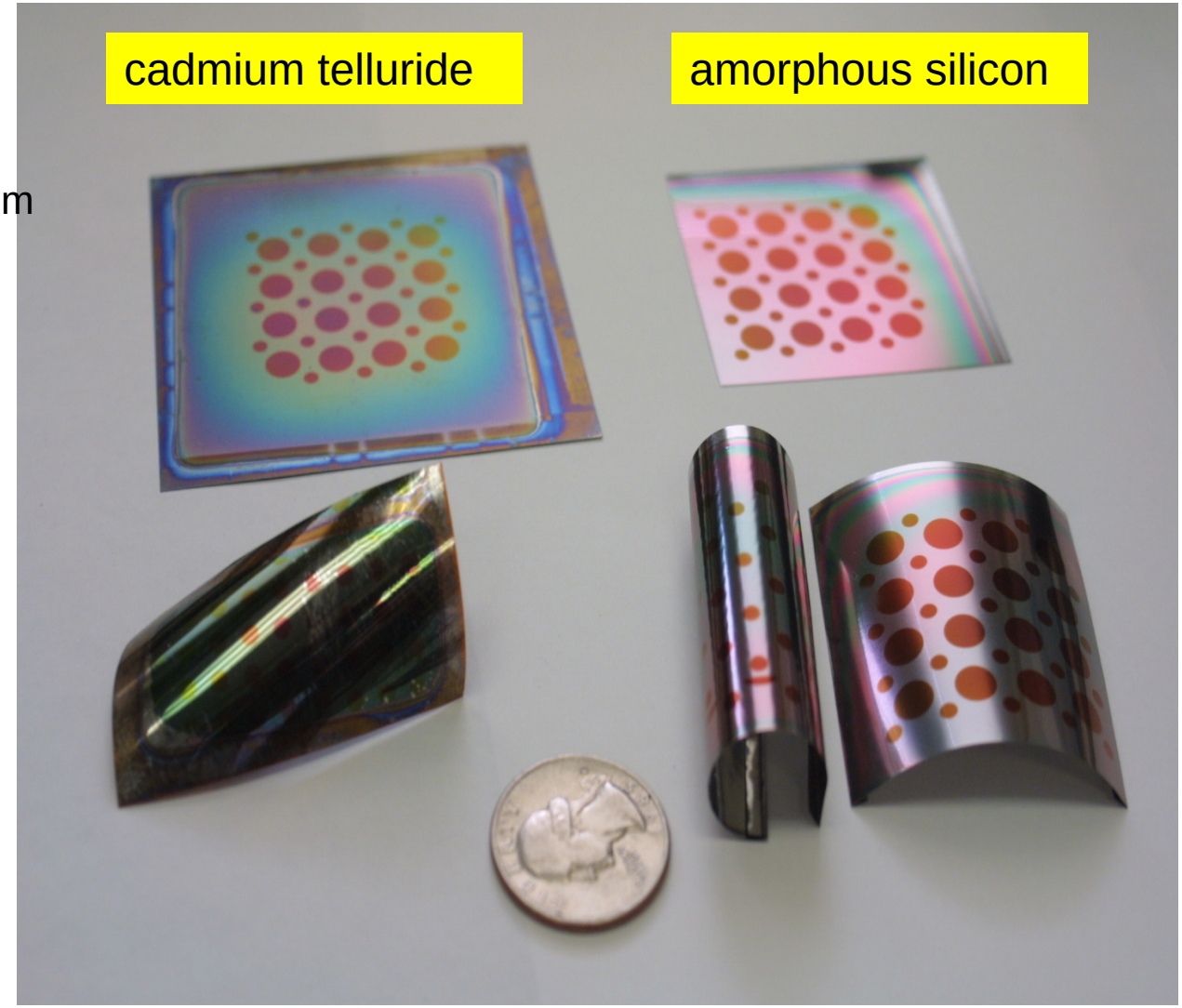
examples of UT's flexible solar cells

cadmium telluride

amorphous silicon

on molybdenum sheet

on stainless steel sheet



on Kapton

on SS foil

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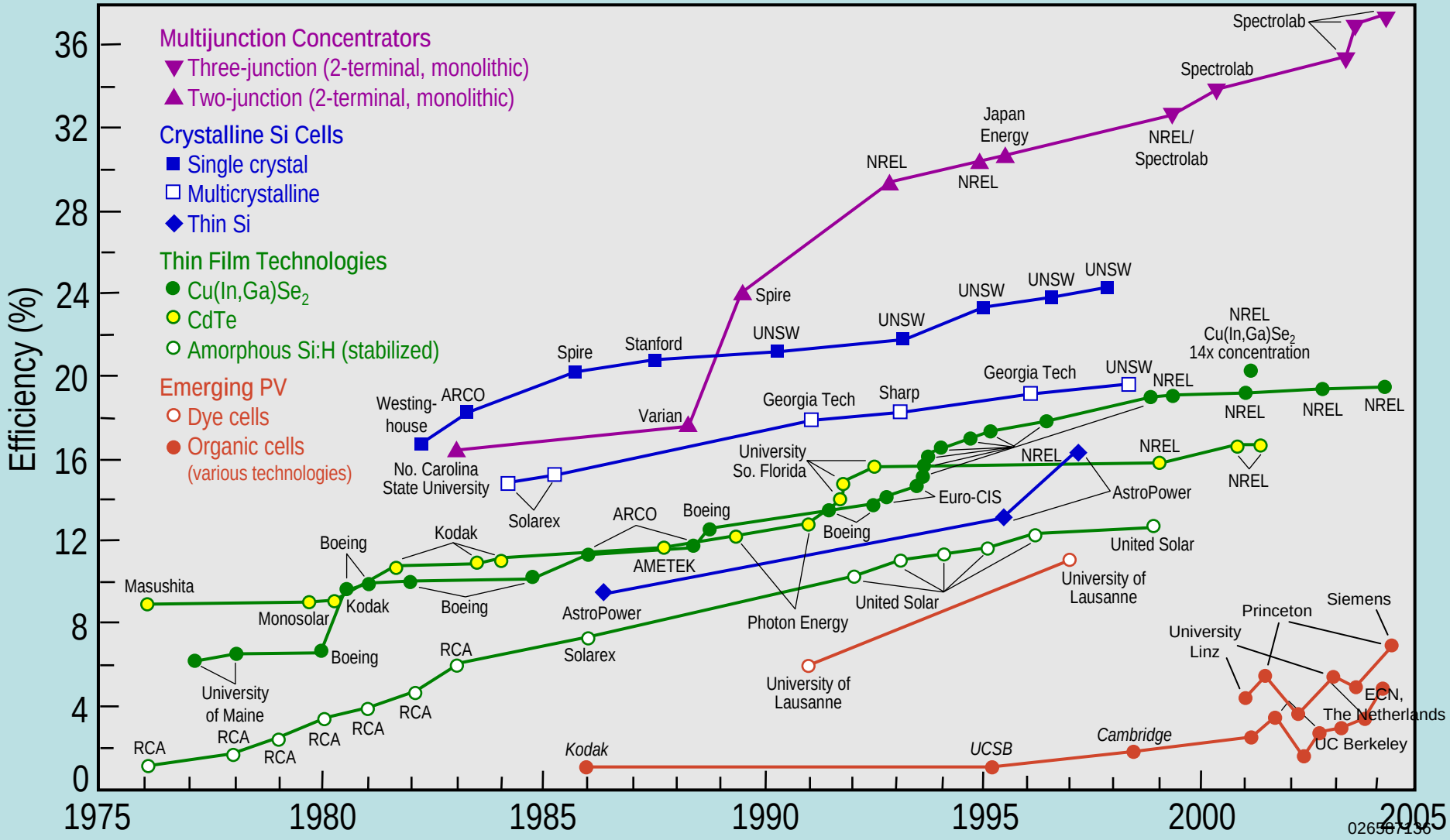
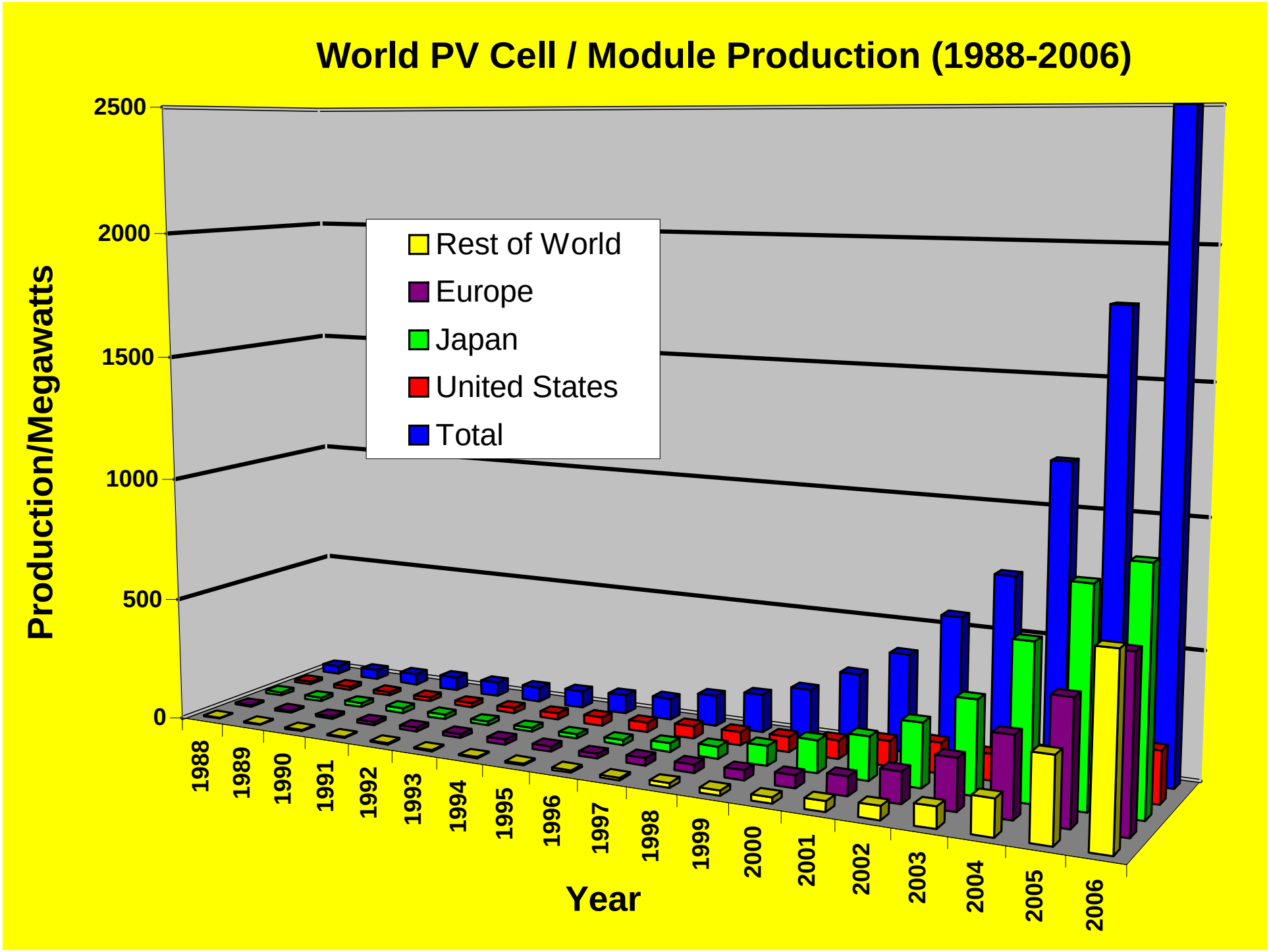
Best Research-Cell Efficiencies

slide from 6/2/05 presentation by Sam Baldwin, Office of Energy Efficiency and Renewable Energy, U.S. DOE

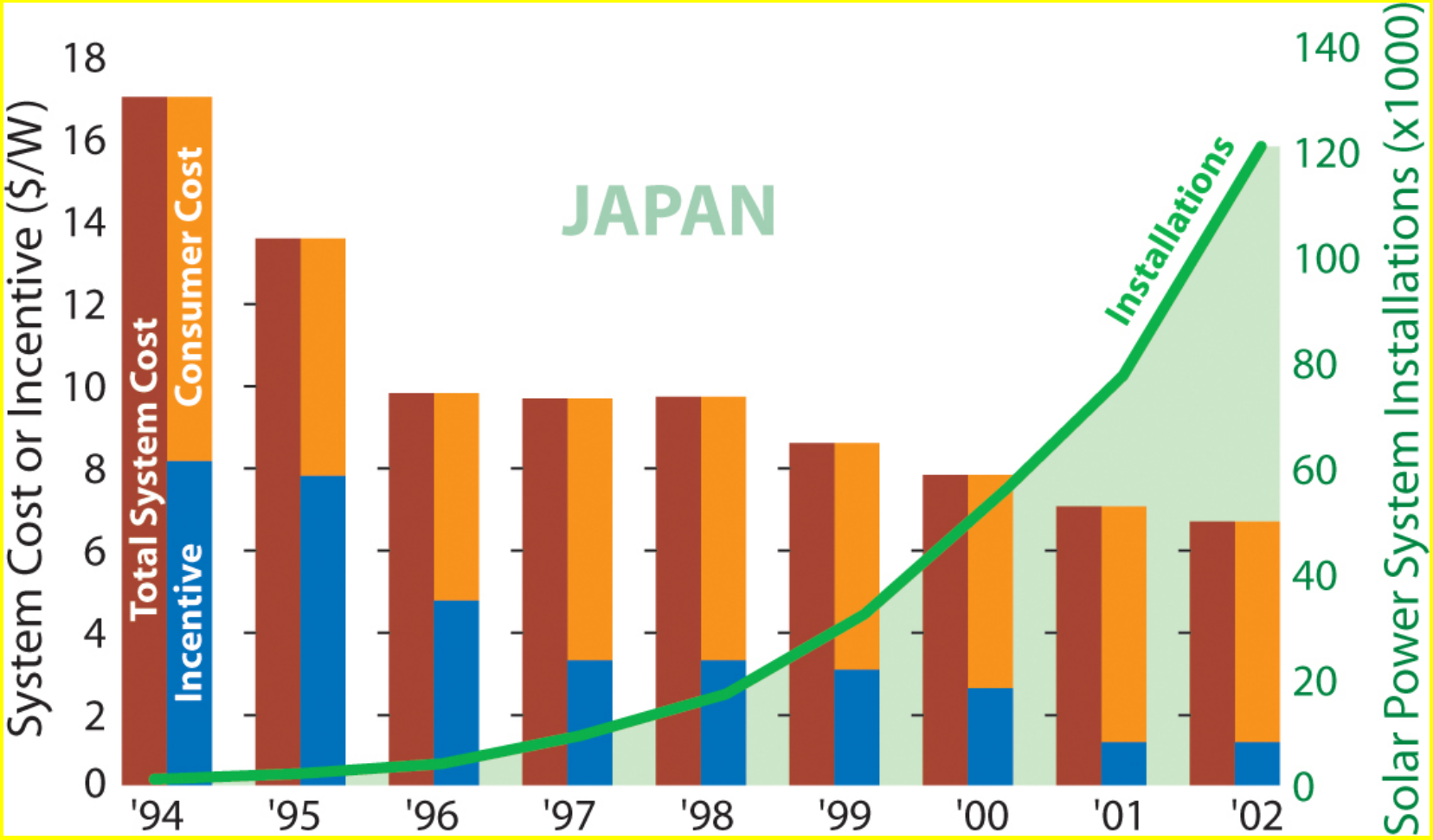


PV industry and market trends


World PV Cell / Module Production (1988-2006)
Production/Megawatts
2500
2000
1500
1000
500
0
Rest of World
Europe
Japan
United States
Total
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year

The Japanese experience with PV incentives

(gov't buydown can play a big role in reducing costs for installed PV)



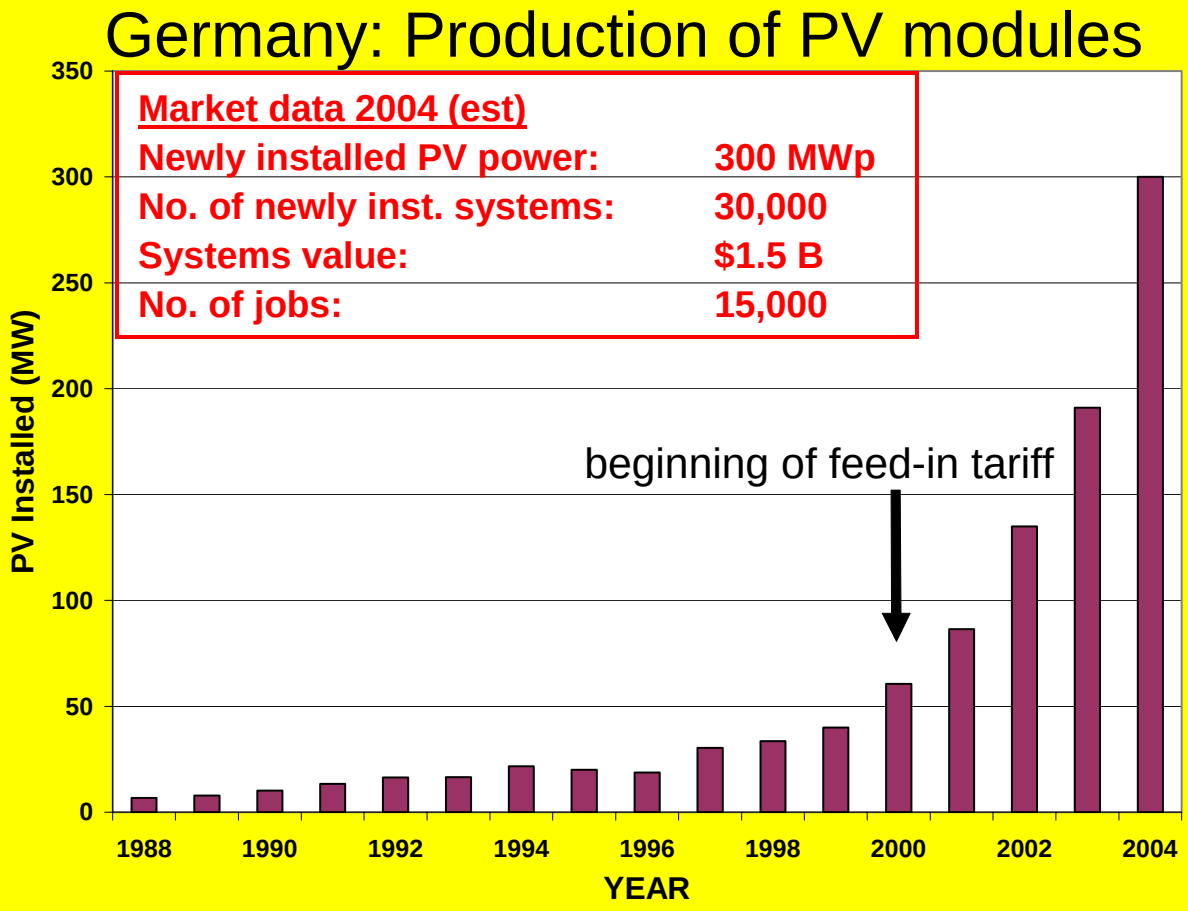
European PV installations have been driven by Germany's "feed-in tariff"

In 2000 Germany instituted a 0.50 Euro/kW-hr ($0.65/kW-hr) payment for electricity delivered to the grid from renewable sources.

(Typical electricity rate is ~0.15 Euro/kW-hr)

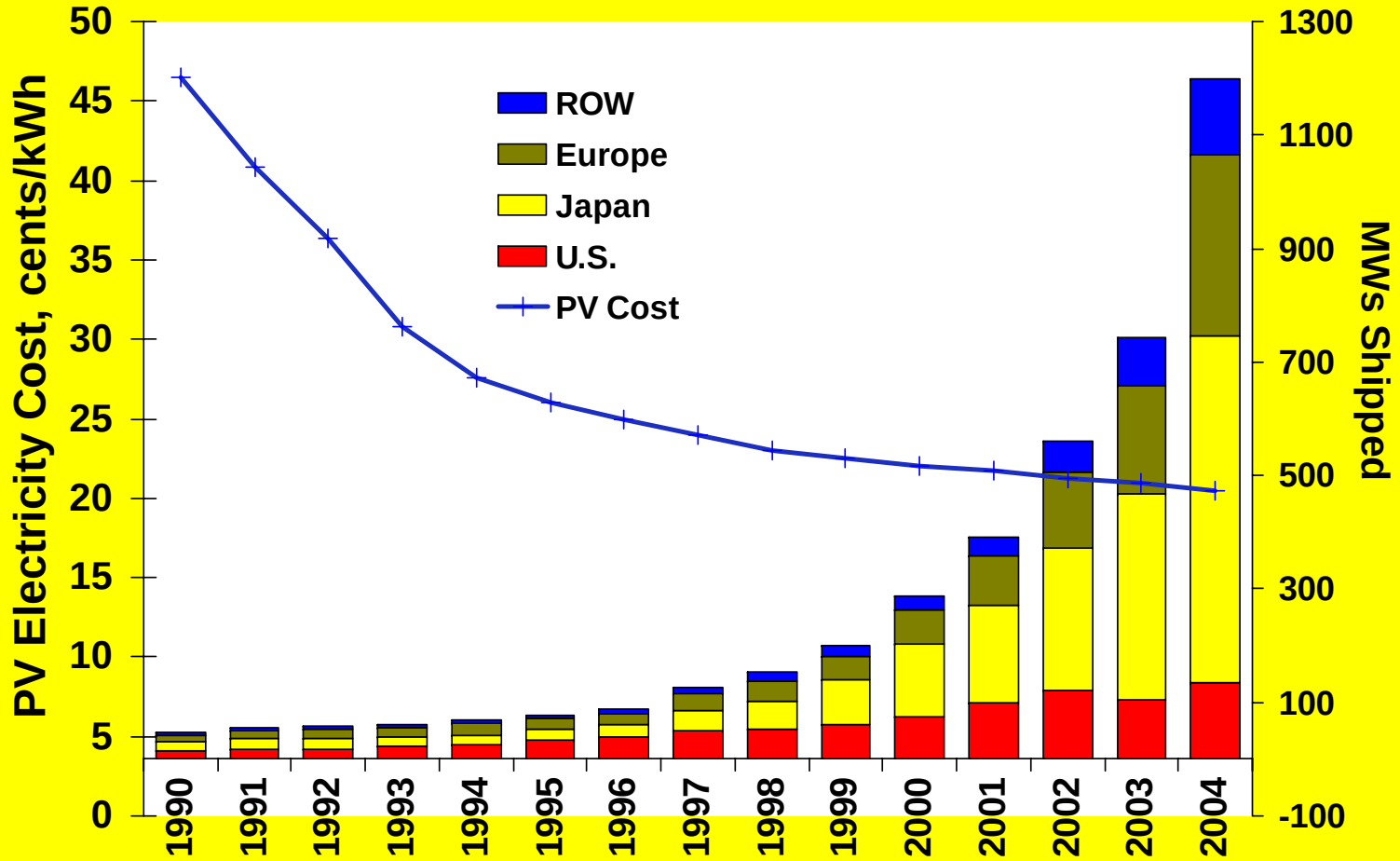
This rewards energy produced rather than subsidizing the original hardware purchase and helps guarantee good maintenance.

Feed-in tariff limited to a total of 350 MWp; phase-out does not occur until end of the year following achievement of the target; then, the Bundestag will have to decide over a new tariff.



PV Costs and Shipments

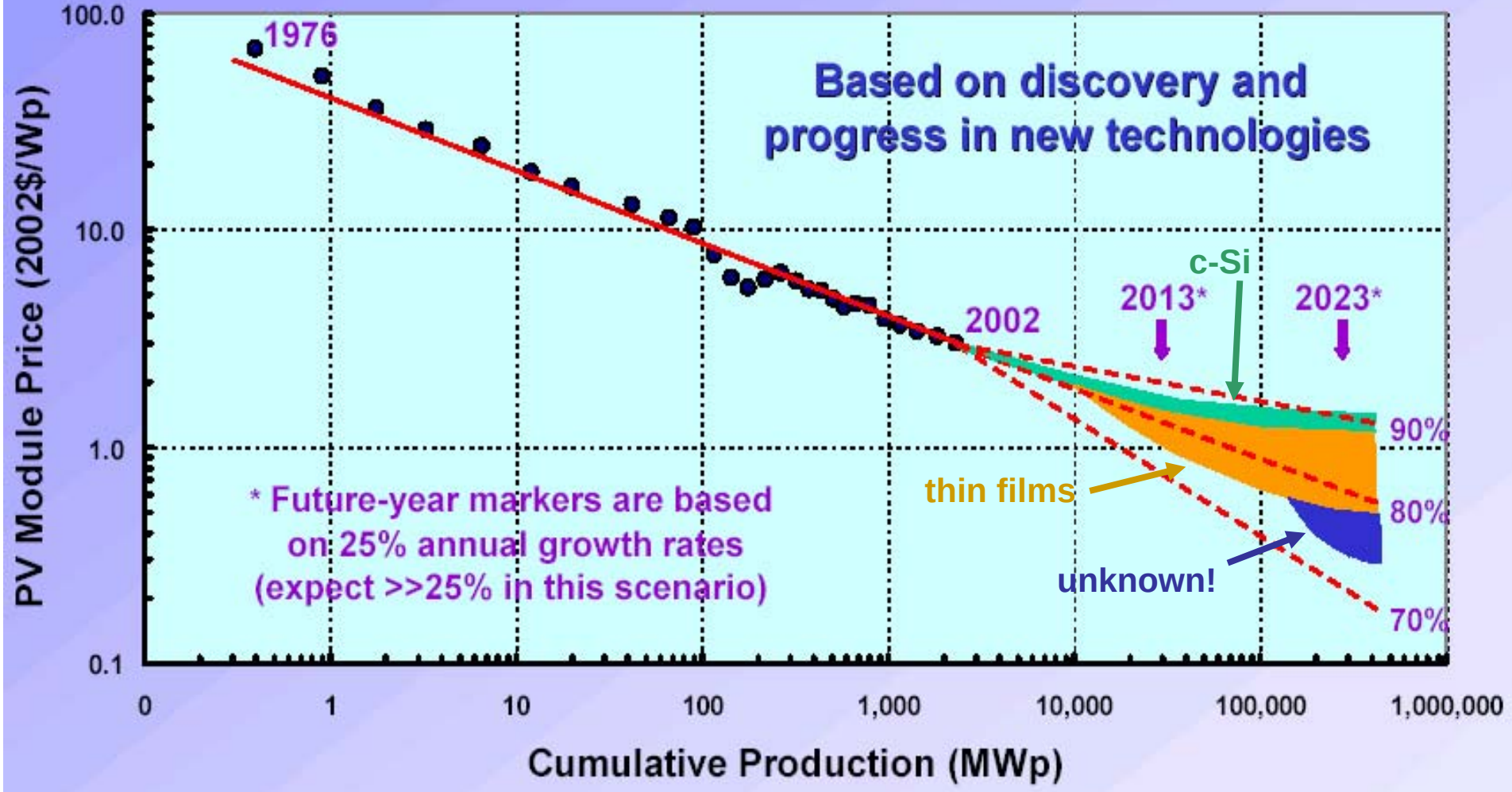
slide from 6/2/05 presentation by Sam Baldwin, Office of Energy Efficiency and Renewable Energy, U.S. DOE



Source for market data: Paul Maycock, PV News, Volume 24, No. 2 February 2005

PV Module Production Experience (or "Learning") Curve

from Tom Surek & Robt Margolis, Third World Conf. on PV Energy Conversion, Osaka, May, 2003



Production of solar modules in the U.S.

Company	2000	2001	2002	2003	2004	2005	2006
Shell Solar	28	39	47	52	62	42	35
BP Solar	21	25	31	13	14	22	25.6
United Solar*	**3**	**4**	**4**	**7**	**14**	**22**	**28**
First Solar*				**3**	**6**	**20**	**60**
GE					25	18	22
AstroPower	18	26	30	17			
Schott Solar	4	5	5	4	10	13	13
Evergreen Solar			2	3	6	14	13
Global Solar				2	1	1	2.5
Other	2	1	3	2	1	1	2.5
TOTAL	**75**	**100**	**121**	**103**	**139**	**153**	**201.6**

*First Solar (Perrysburg) & UniSolar (Auburn Hills) are thin-film PV manufacturers.

a zero-electric-energy home in Toledo
(PV works easily in Ohio)

solar power in Toledo, OH

energy-star home built to be a net zero user of grid electricity (“zero-energy home”)

- home built by Decker Homes
- PV mfg by First Solar
- PV installed by Advanced DG
- With support from ODOD-OEE

roof racks and electrical feed-throughs

installation of First Solar modules by John and Mark of Advanced DG


LECTRK

the DC to AC inverters
(360 V_{DC} to 220 V_{AC})

the readout/computer interface

powered by 20 six-volt deep-discharge lead-acid batteries

Web site for the latest performance data:

www.home.earthlink.net/~alcompaan

Not only is the e-truck charged with solar, it can power up the house for emergencies…

Exeltech inverters with transfer switch and subpanel circuits for:

furnace, water heater, sump pump, kitchen, master bedroom


LECTRK


Governor's Award for Excellence in Energy Efficiency
Governor's Award for Excellence in Energy Efficiency
A Solar Powered
Home and E-Truck
with Ohio-made PV

the cost of our solar power for our home and truck

- $50,000 for a 4.3 kW system
- ~$7,000 for connection from truck to home
- thus ~$10/$W_p$ for home and truck power
- for home alone (w/o truck) we would need only 2 to 2.5 kW system ($20,000-$25,000)
- PV panels cost $3/$W_p$
- inverters cost $1.50/$W_p$
- BOS (design, installation, wiring, permits) cost was $5.50/$W_p$

credits for the home solar system:

- 50% financial support from the Ohio Department of Development, Office of Energy Efficiency—Energy Loan Fund
- First Solar (PV panels)
- Decker Homes (contractor)
- Advanced Distributed Generation (PV install)
- David, Mary, Luke for the e-conversion

thoughts about PV in Ohio

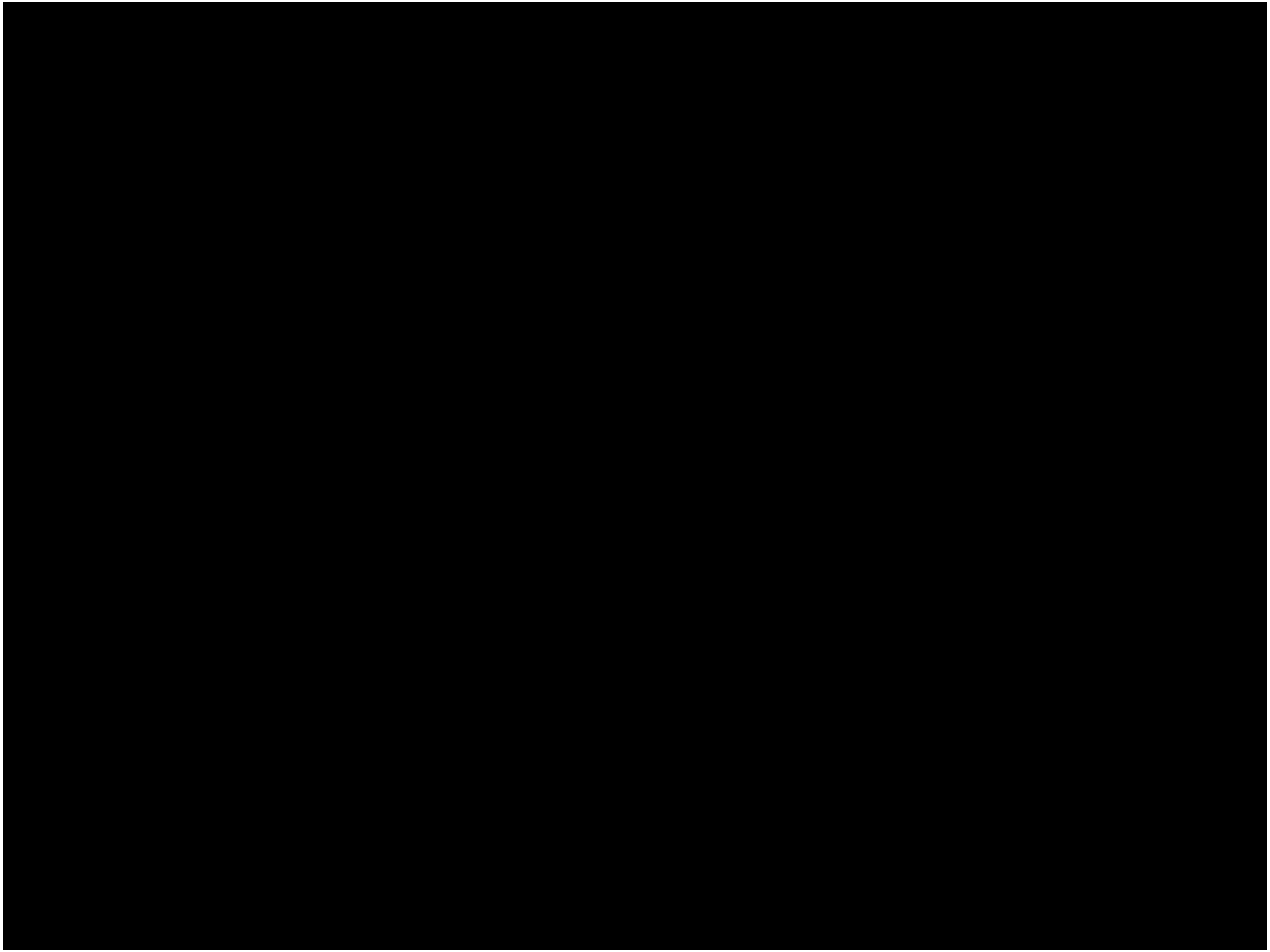
- solar-powered commuting and solar living work just fine in Toledo!
- a grid-tied system is seamless
- no maintenance issues the first 18 months
- thin-film on glass panels are attractive and very functional

Web site for the latest performance data:

www.home.earthlink.net/~alcompaan

Conclusions--PV in the big picture

- Steadily improving PV efficiencies
- Production increasing 40% per year
- Price reductions follow 80% learning curve
- Grid-connected applications now dominate
- Market incentives have stimulated growth (Japan, Germany, some U.S. states)
- PV can become a major source of U.S. power
- **NW Ohio/SE Michigan is poised to be the world leader in PV production!**
- **PV can become a major job-creator in Ohio!**



PVIC: Center for Photovoltaics Innovation and Commercialization @ University of Toledo

An $18.6 M Third Frontier Wright Center of Innovation Award: Center for Photovoltaics Innovation and Commercialization

- *3 Ohio Universities:*
  - ***University of Toledo: Lead Institution***
  - *Ohio State University*
  - *Bowling Green State University*
- *4 Ohio Not-for-Profit Organizations:*
  - *Battelle Memorial Institute*
  - *Green Energy Ohio*
  - *Edison Materials Technology Center*
  - *Honda OSU Partnership*
- *13 Ohio Companies:*
  - *Advanced Distributed Generation*
  - *Cornerstone Research Group*
  - *Decker Homes*
  - *DuPont*
  - *Innovative Thin Films*
  - *LakeShore Cryotronics*
  - *Metamateria Partners*
  - *Midwest Optoelectronics*
  - *NewCyte*
  - *Owens Corning*
  - *Pilkington*
  - *Solar Fields*
  - *SSOE*

Center for Photovoltaics Innovation and Commercialization

PVIC: Center for Photovoltaics Innovation and Commercialization @ University of Toledo

Overview of State of Ohio Funding for PVIC

Financial overview of PVIC (over three years):

capital funds	**$11 M**
UT	$5.1M
OSU	3.5M
BGSU	2.4M
operating funds	**$7.6 M**
UT	$4.24M
OSU	3.27M
BGSU	0.09M
total State funds	**$18.6 M**
UT	$9.34M
OSU	6.77M
BGSU	2.49M

[Total matching funds $29 M]

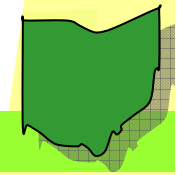
University of Toledo Clean and Alternative Energy Incubator

Researcher operating electrical probe station in cleanroom of OSU Nanotech West Lab

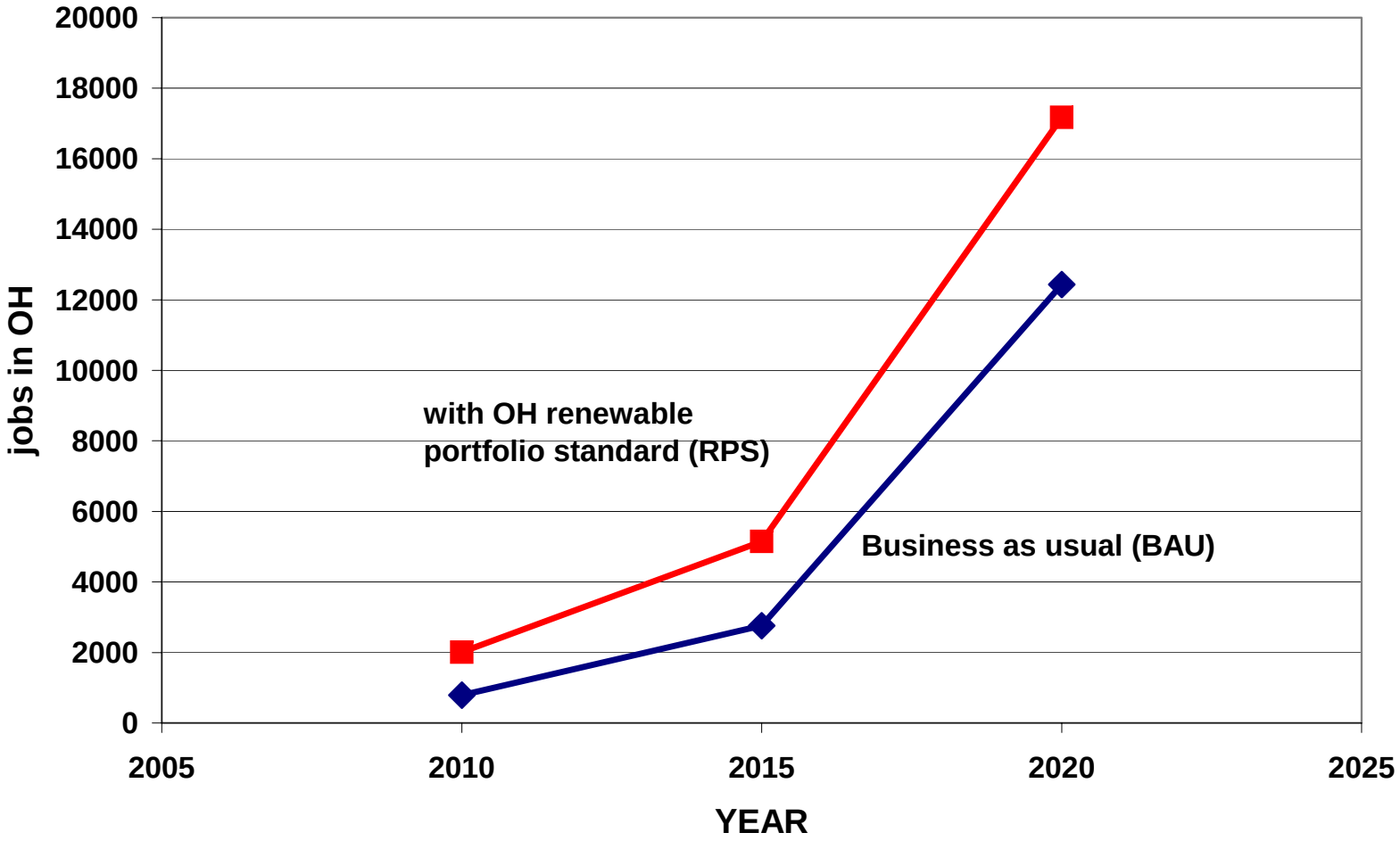
Sustainability Goal: continue innovation growth with operating fund revenue growing from $2.5 M/yr

.... energizing Ohio for the 21st Century

NW Ohio can lead the way in PV job creation

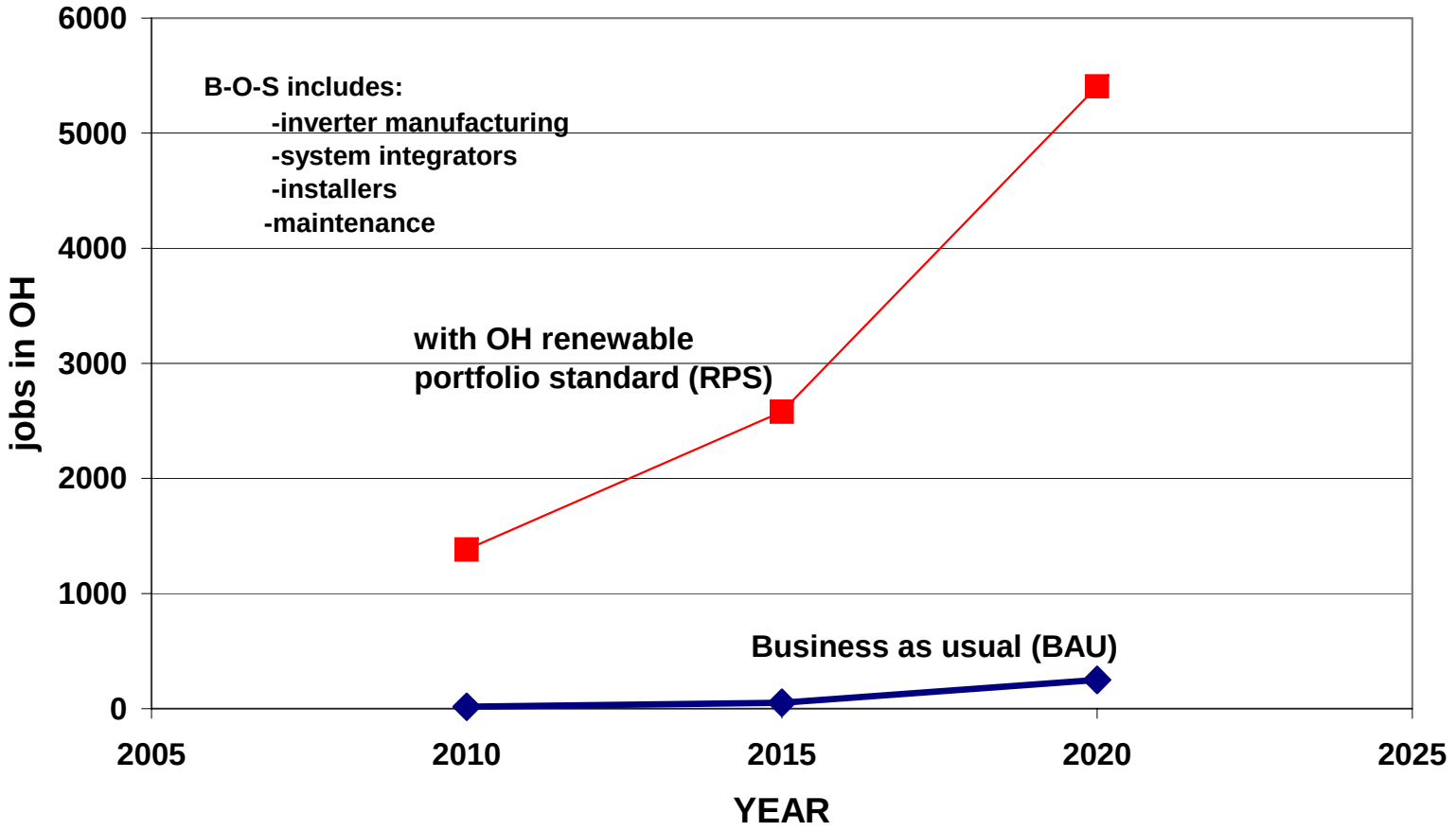


PV Research and Development jobs in Ohio



source: Navigant Consulting Inc, June 2006

PV Balance-of-systems jobs in Ohio



source: Navigant Consulting Inc, June 2006

Center for Photovoltaics Innovation and Commercialization

PVIC: Center for Photovoltaics Innovation and Commercialization @ University of Toledo

PVIC Organizational Chart

Scientific Advisory Board

Executive Industrial Advisory Board

PVIC Co-Directors:
Robert Collins (UT) & Robert Davis (OSU)

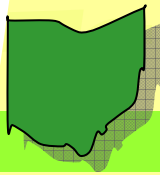
Time to Consumer (in yrs.)

Time to Consumer (in yrs.)	Areas	University Coordinator	Industry Coordinator
> 9	1: Science & Tech. Foundation	Phil Castellano, Bowling Green State U.	Dennis Flood, NewCyte
6 - 9	2: Device Development	Steve Ringel, Ohio State U.	Xunming Deng, MWOE Solar
3 - 6	3: System Components	Sylvain Marsillac, U. Toledo	Norm Johnston, Solar Fields
0 - 3	4: Full System Integration	Al Compaan, U. Toledo	Joe Kunkle, SSOE, Inc.
0	5: Education, Consumer & Public Awareness	NGO's: Bill Spratley and GEO	

PVIC Staff and Facilities

The Photovoltaics Value Chain in Ohio:
From Novel Materials to Complete Systems and Public Awareness

PVIC IP Innovation Council
Alex Kawczak, Battelle



.... energizing Ohio for the 21st Century