

Solar Research at ORNL

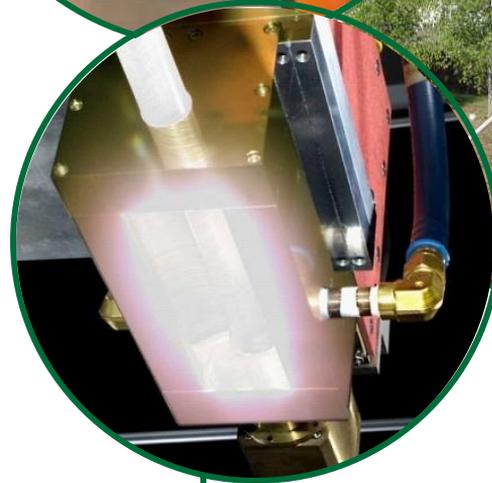
Chad Duty

Solar Technologies Program Manager

ORNL User Week 2010

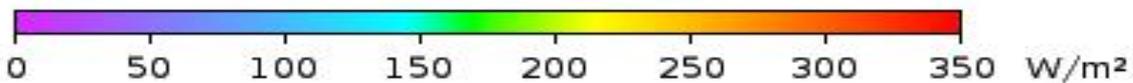
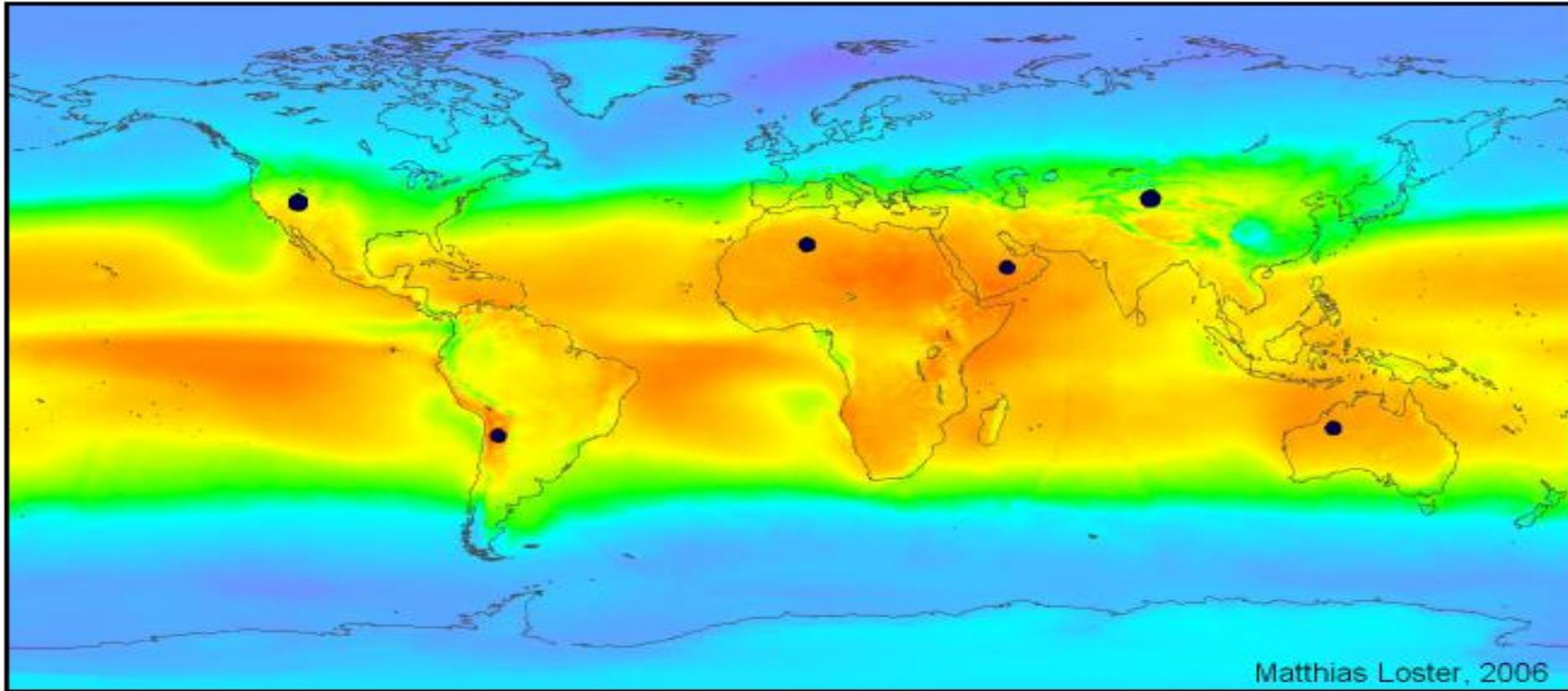
**Solar Energy and Energy Storage:
Answering the Energy Challenge**

September 14, 2010



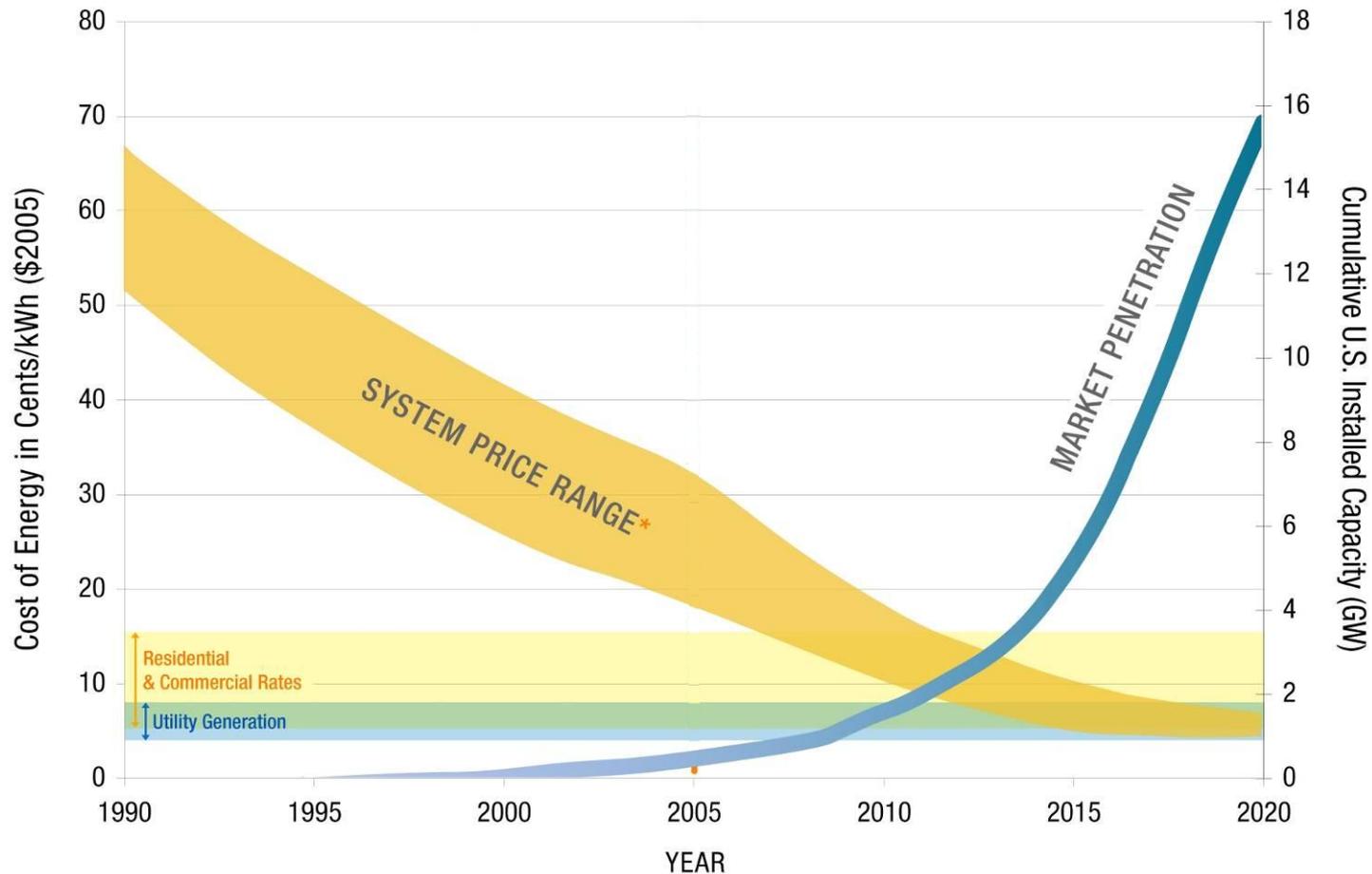
Enough Energy to Go Around...

Average Insolation (radiation energy / area)



$\Sigma \bullet = 18 \text{ TWe}$

Solar America Initiative Goal: Grid Parity by 2015



Market Sector	Price Range (¢/kWh)	Benchmark 2005	Target 2010	Target 2015
Residential	5.8-16.7	23-32	13-18	8-10
Commercial	5.4-15.0	16-22	9-12	6-8
Utility	4.0-7.6	13-22	10-15	5-7

Levelized Cost of Energy

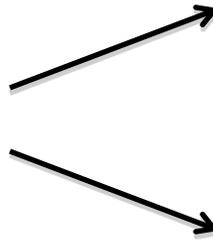
Primary Metric

(LCOE)

$$\frac{\$}{\text{kWh}}$$



$$\frac{\$}{\text{Wp}}$$



Secondary Metrics

Manufacturing Cost

$$\frac{\$}{\text{m}^2}$$

\$150 - \$300 / m²

< \$100 / m²

Efficiency

$$\frac{\text{Wp}}{\text{m}^2}$$

Lab (TF) = 20%

Com (TF) = 10%

Commercial = 20%

Current

$$\frac{\sim \$0.25}{\text{kWh}}$$

$$\frac{\$1.5 - \$3.5}{\text{Wp}}$$

Goal

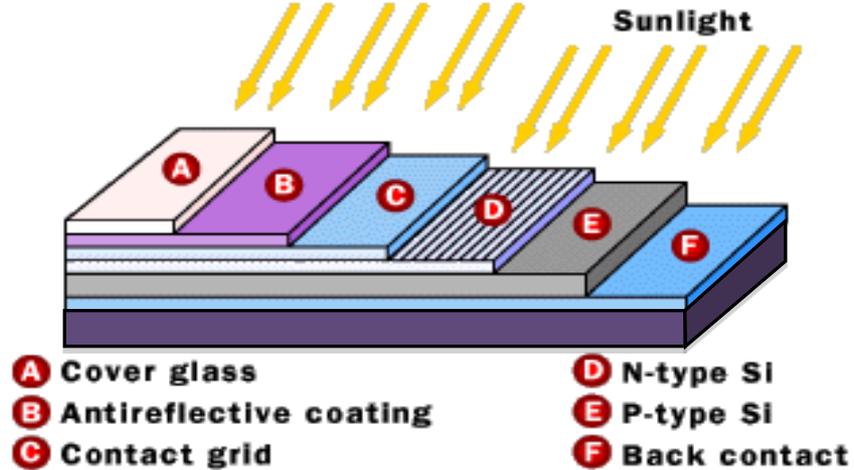
$$\frac{< \$0.07}{\text{kWh}}$$

$$\frac{< \$1}{\text{Wp}}$$

Reducing Manufacturing Cost

Materials Choice

Thinner
Cheaper
Earth Abundant
Non-Toxic



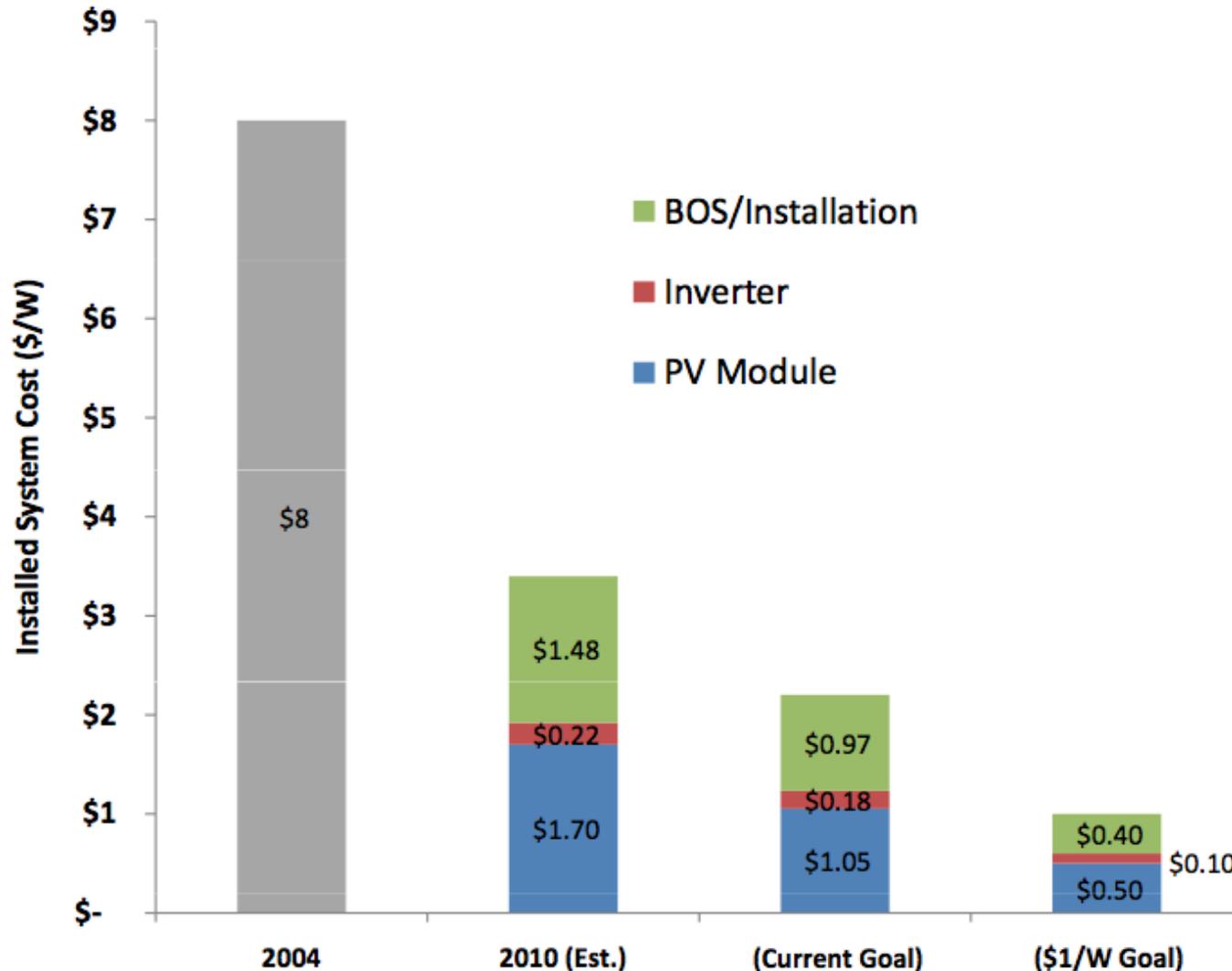
Alternate Processes

Non-Vacuum
Large Area
Continuous (R2R)
High Throughput
Standardization



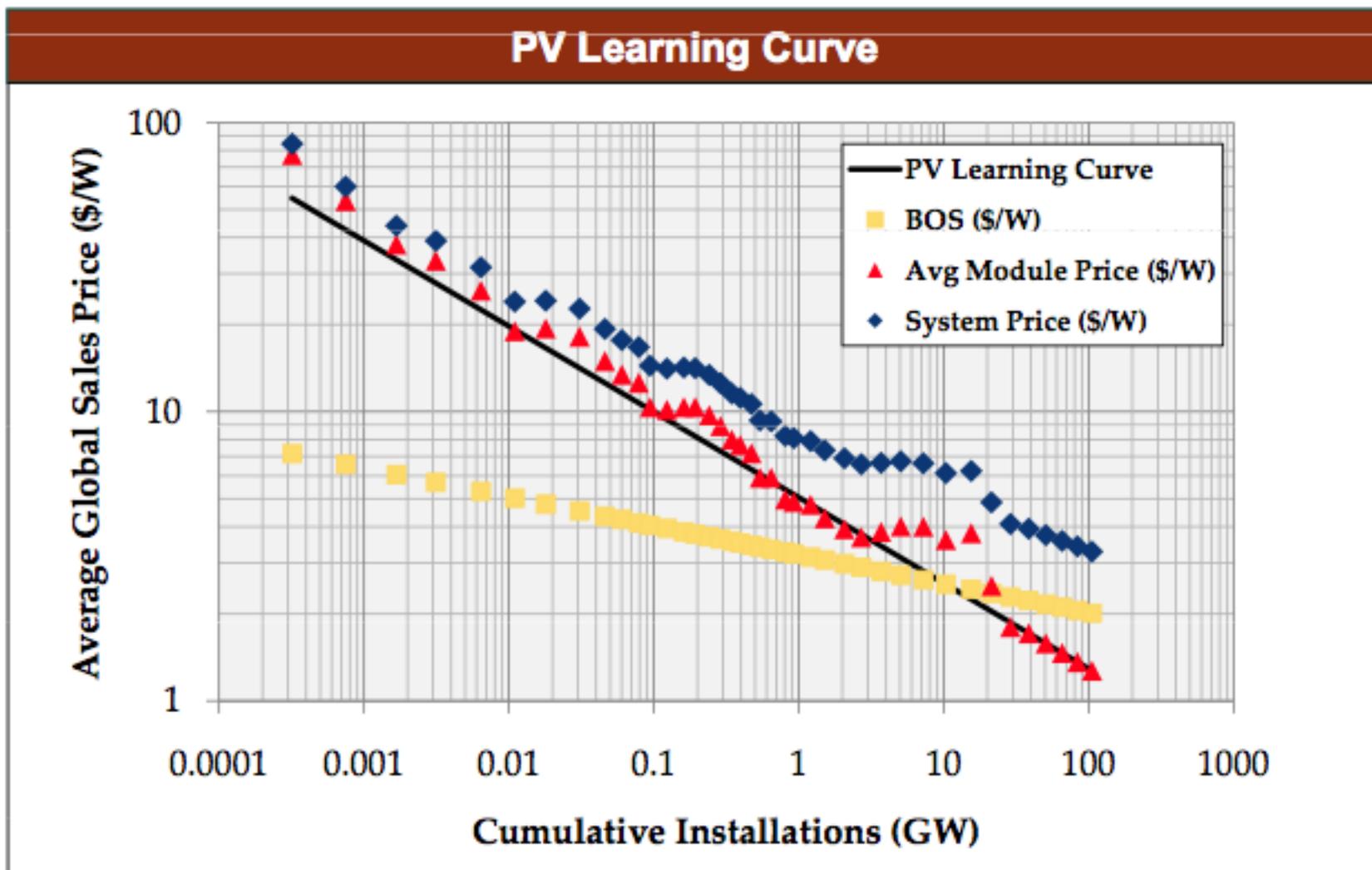
Reducing PV System Cost

PV system cost consist of 3 primary factors: Modules, Electronics, BOS



Reducing PV System Cost

Learning rates for PV systems will decrease as Balance of Systems (BOS) costs begin to dominate total installation price.



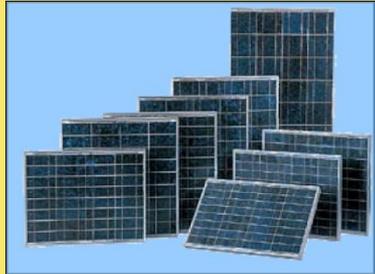
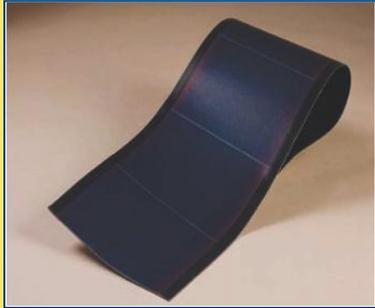
Lab-scale Efficiency → Marketplace

	<u>Market Share</u>	<u>Research</u>	<u>Commercial</u>
Crystalline Silicon	85%	25%	20%
Amorphous Silicon	5%	13%	10%
Thin Film CdTe	8%	17%	11%
Thin Film CIGS	1-2%	20%	13%
Organic PV	<1%	~5%	1-2%

Note: Shockley-Queisser Limit \approx 33%

Solar Research at ORNL

Technology Development



**Materials Research,
Characterization, &
Process Optimization**

Systems Integration



**Power electronics
Electric grid**

Concentrated Solar



**Heat transfer fluids
High temperature
materials**

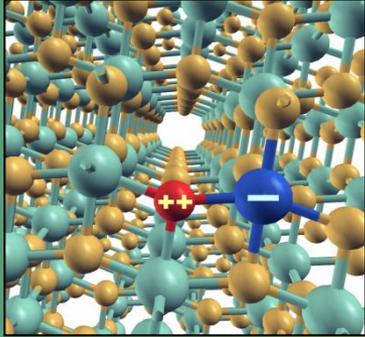
Market Transformation



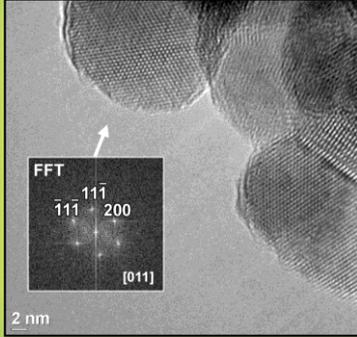
**Large-scale deployment
Reduce barriers**

ORNL Solar Materials Research

SCIENCE...



Modeling



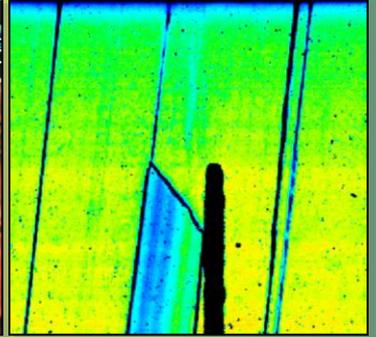
Novel Materials



Synthesis

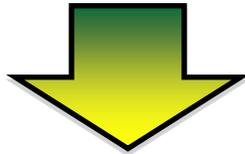


Processing

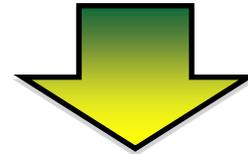


Characterization

Unique Capabilities



Experienced Research Staff



Industrial Collaboration

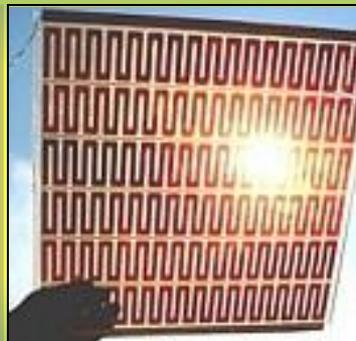
TO ENERGY!



Thin Film PV



Organic PV



Dye Sensitized Solar Cells



Concentrated Solar Power



Tech Transfer

Photovoltaic Research

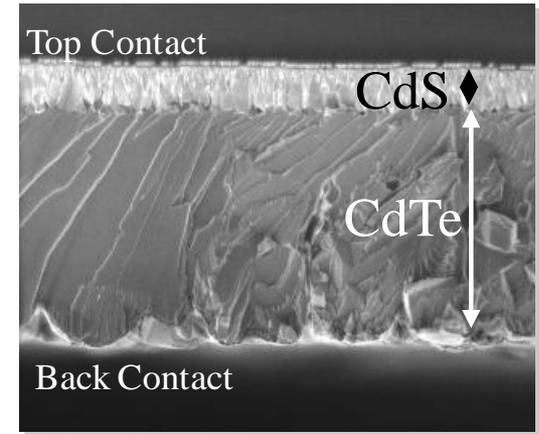
Fundamental Research

How does CdTe PV work?

Why does polycrystalline outperform single crystal?

Role of defects? Vapor CdCl treatment?

New materials (non-toxic, earth abundant)



Applied Research

High volume roll-to-roll manufacturing

Non-vacuum deposition techniques

Compositional control and thermal processing



Industrial Collaborations

Recognized strength of ORNL (148 R&D100 Awards)

ITP Solar Program (\$3M) to develop projects initiated by solar industry partners

Leverage TN Solar Initiative

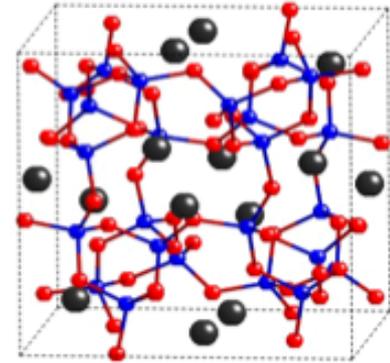


Solar Research Initiative

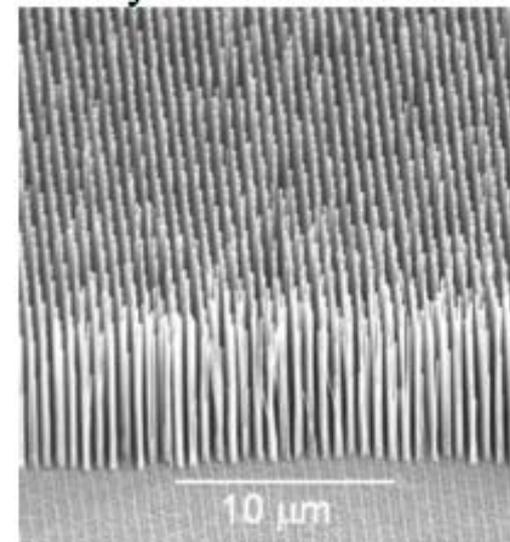
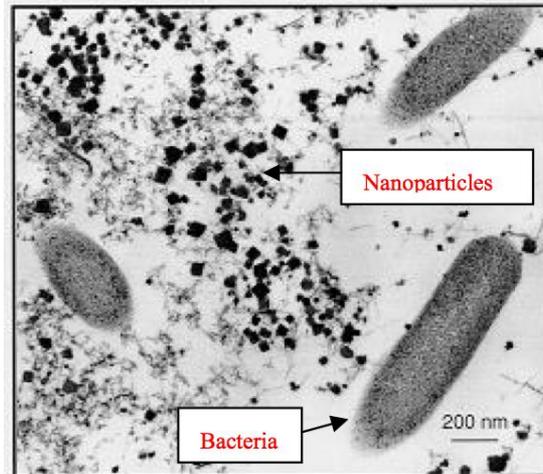
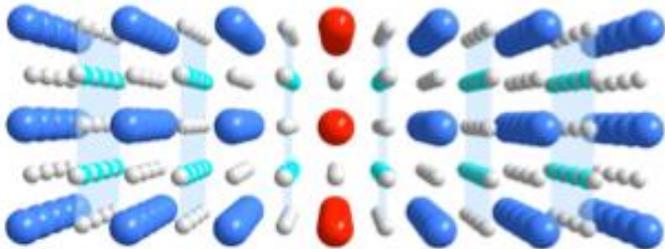
Laboratory Directed Research & Development

Basic

- Polar & Non-Polar Oxide Heterojunctions – H. Lee
- Self-Organized Interfaces for OPV – M. Kilbey
- New Multinary Inorganic Materials – M. McGuire
- Nanostructured PV Solar Cells – J. Xu
- Low Cost Manufacturing of CIGS Thin Films – L. Love



Applied

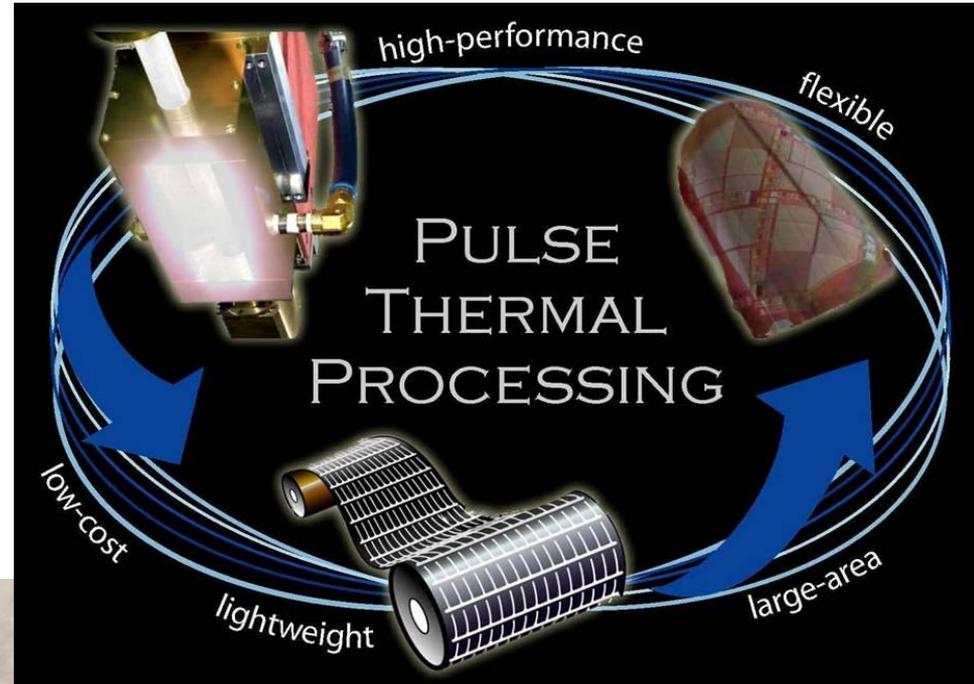


Pulse Thermal Processing / PulseForge

A new technology for high-speed drying, curing, sintering, or annealing of high-temperature materials on plastic and paper substrates.

Characteristics:

- Energy Flux in excess of 20 kW/cm²
- Heating Rates up to 600,000°C/s
- Exposure Time on (ms) and (μs) scale



Thin Film Solar Research at ORNL

Collaborative Projects with Industry Partners

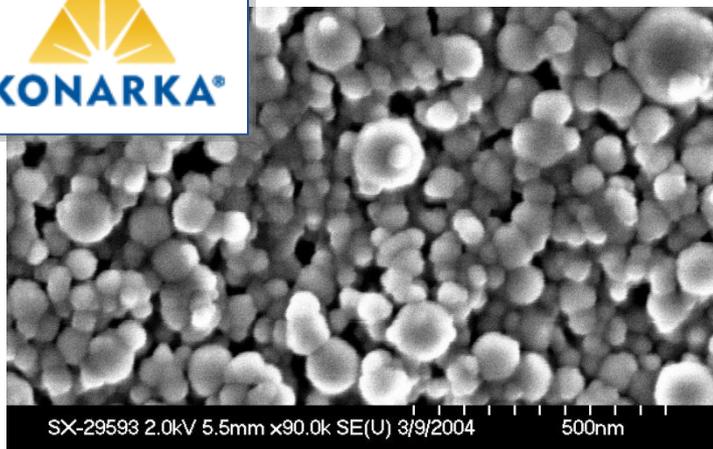
Crystallize Amorphous Silicon on Metal Foil Substrate



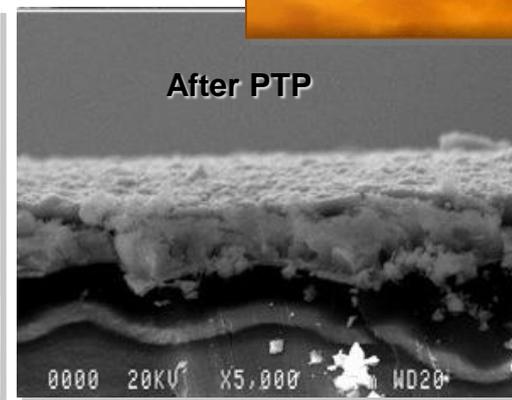
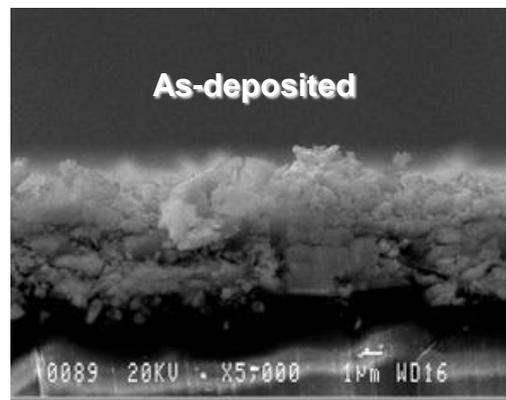
Low Cost Polycrystalline CdTe on Kapton Substrate



Texturing of CIGS Nanocrystals on Polymer



14 Sintered TiO_2 Nanoparticles on Polymer
for the U.S. Department of Energy



Grain Boundary Refinement Increased CIGS Thin Film Efficiency by 50%



Rapid Synthesis of CIGS



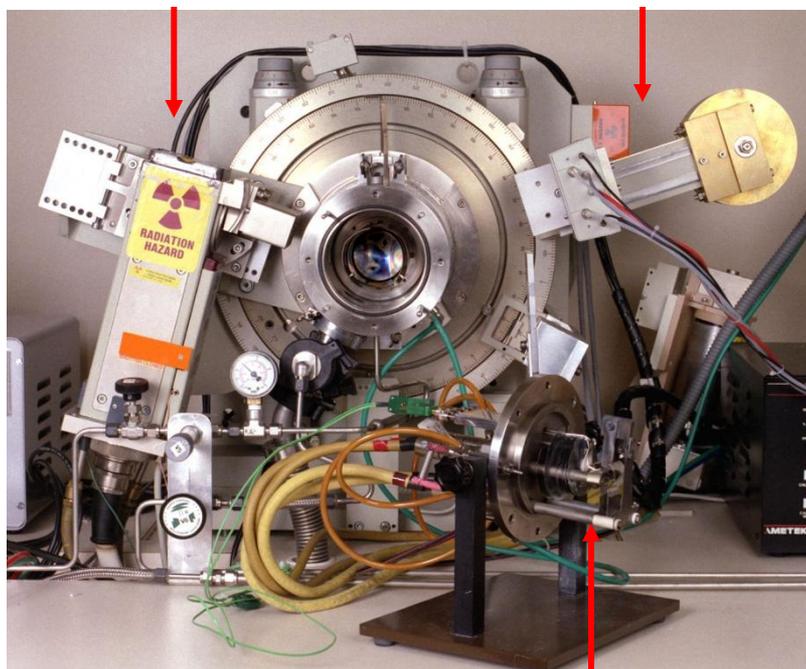
Objective:

Determine the reaction pathway for synthesis of CuGaSe_2 , CuInSe_2 , and $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ from basic precursor structures using HT-XRD, GIXRD, and TEM

High Temperature XRD System

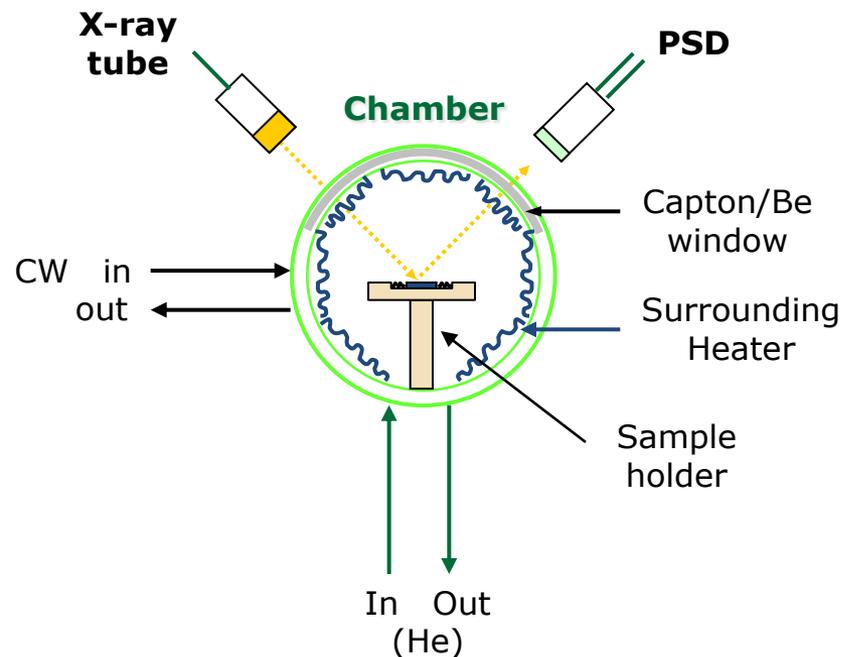
X-ray tube

Linear PSD



Strip heater

Panalytical Philips X'pert System



Flexible Epitaxial PV Films

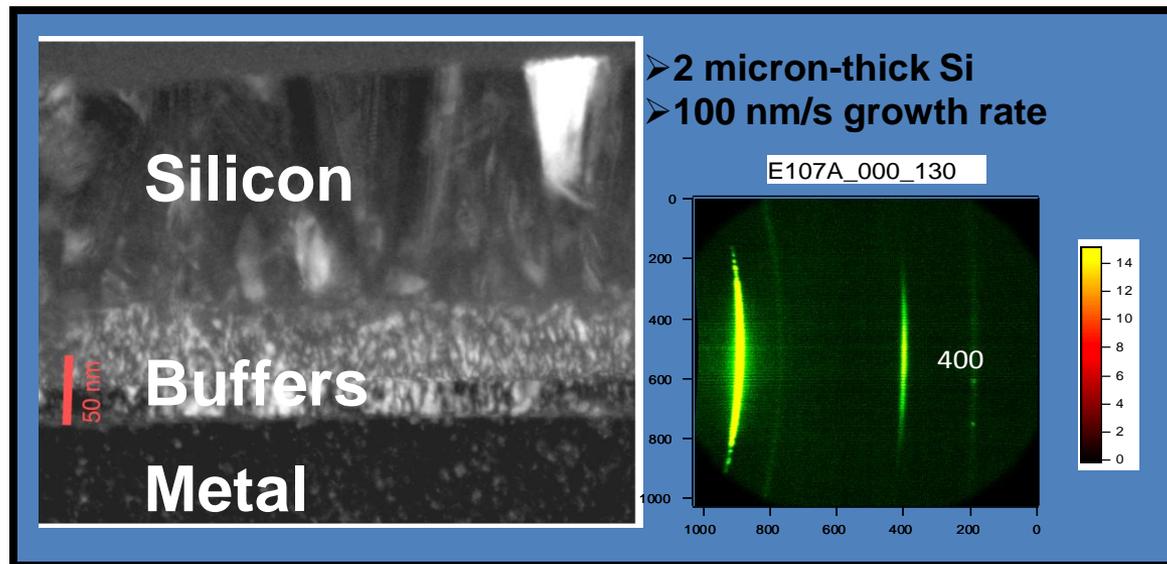
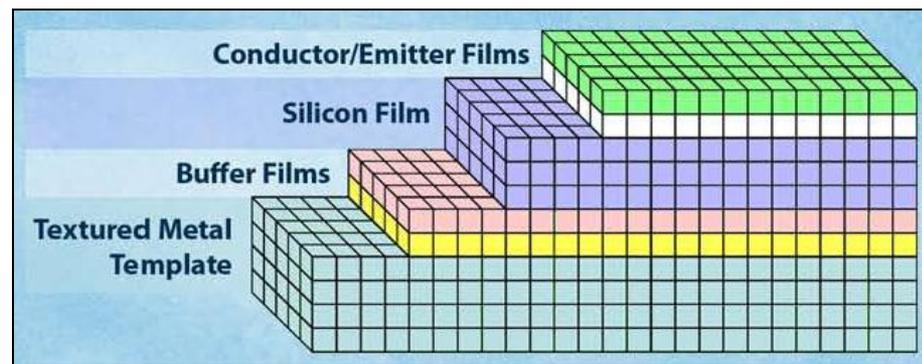


Objective:

Develop and commercialize high-efficient and low-cost photovoltaic films on flexible single crystal-like substrates suitable for mass production

- ✓ Developed single crystal-like substrate for PV films.
 - Scalable and potentially low-cost process.
- ✓ Deposited epitaxial PV films on flexible textured substrates.
 - Scalable and potentially high-efficiency energy source.

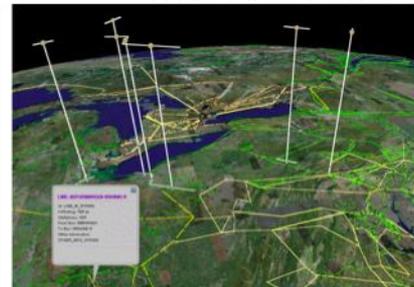
Awarded 2008 Best Early Seed Investment of the Year



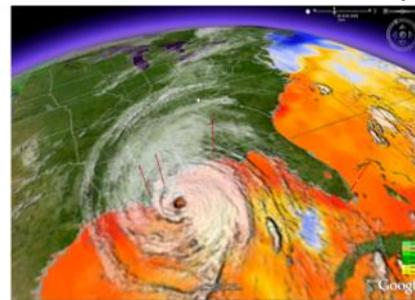
Power and Energy Systems Group

- A staff of 12 researchers
- World class facilities
 - Distributed Energy Communications and Control Facility (DECC)
 - Visualizing Energy Resources Dynamically on Earth (VERDE)
 - Powerline Conductor Accelerated Testing Facility (PCAT)
- The group is actively involved in partnerships with several universities, private and public companies, other federal agencies, and consortiums.
- Projects supported by various offices of DOE, DHS, and industry.

Wide-Area Power Grid Situational Awareness



Real-time Weather Overlays



Impact Models



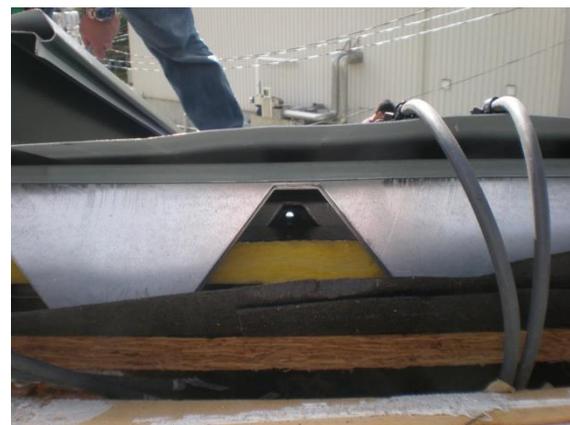
Building Integrated PV



Solar retro-fit strategy with PCM
30% energy savings

Dynamic Test Roof Facility

- Solar panel as component to active building envelope
- Phase Change Material (PCM) for thermal management
- Durability testing of commercial PV cells



Durability Testing: Poor inter-layer adhesion



Market Transformation

Campbell Creek Research Houses (2400 ft²)

- Compare “as-is”, new build, and “retro-fit” houses
- Energy saving and alternative energy approaches

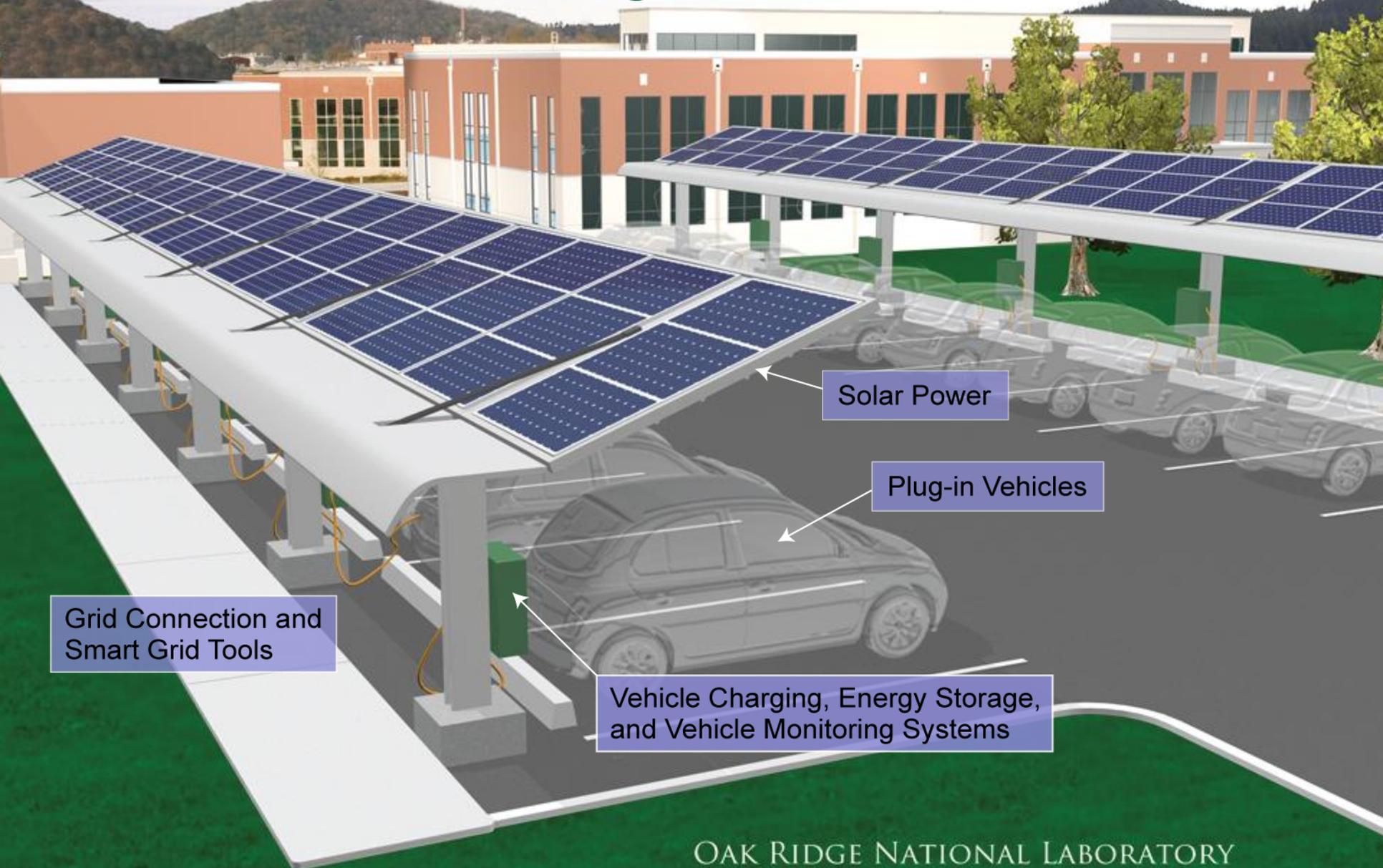


ZEB Alliance



Zero Energy Building
Research Alliance

Systems Integration of Renewables



Grid Connection and
Smart Grid Tools

Solar Power

Plug-in Vehicles

Vehicle Charging, Energy Storage,
and Vehicle Monitoring Systems

OAK RIDGE NATIONAL LABORATORY
SUSTAINABLE CAMPUS INITIATIVE

Photovoltaic Material Manufacturing Collaborative Research Opportunity

Oak Ridge National Laboratory (ORNL) will conduct short-term, focused research projects to address specific needs of the solar industry.

The goal is to decrease the levelized cost of energy (LCOE) of solar energy through increased performance or decreased manufacturing cost.

Funding: ~\$100,000 per project (ORNL internal funds)

of Projects: 4 to 5

Duration: 6 months

Cost Share: 50% (funds-in or in-kind)

Projects will be selected based on a brief proposal (5 pages)

Review Begins: November 1, 2010

Project Selection: November 15, 2010

Submission / Inquiries: indtech@ornl.gov





In 1931, not long before he died, Edison told his friends Henry Ford and Harvey Firestone:

“I’d put my money on the sun and solar energy. What a source of power! I hope we don’t have to wait until oil and coal run out before we tackle that”