NSERC Planning Workshop

Don Warfield, BP Solar

Historical Background

- **1839** Photovoltaic effect discovered by Edmond Becquerel
- **1921** The Nobel Prize in Physics is awarded to Albert Einstein "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect"
- **1954** First silicon p/n junction solar cell made at Bell Labs
- **1958** Solar cells used to power satellites (Vanguard I)
- **1973** Solarex established, spin-off of Comsat Labs (J.L Lindmeyer, P.Varadi)
- **1979** Invention of Solarex poly-crystalline silicon process
- **1980** BP enters solar industry via purchase of Lucas Energy Systems
- **1985** BP Solar acquires license for Laser Grooved Buried Grid Process
- **1997** Solarex (then 50% owned by ENRON) started production of amorphous silicon modules
- **1999** BP and Amoco merge (ENRON bought out), BP Solarex formed
- **2000** BP Solar consolidated
- **2004** IntegraBus ™ and Integra frame
- **2007** Mono² ™ Casting developped
- **2010** LISF project started

Remote Application: Water Pumping

Remote Application: Education

BP Solar modules provide electricity to 1,852 schools in Brazil: lights, TV/Satellite/video and refrigerator.

Residential Retrofit

Residential Retrofit

Roof Integration: EnergyTile™

Residential Roof Application

Building PV Curtain Wall

Georgetown University

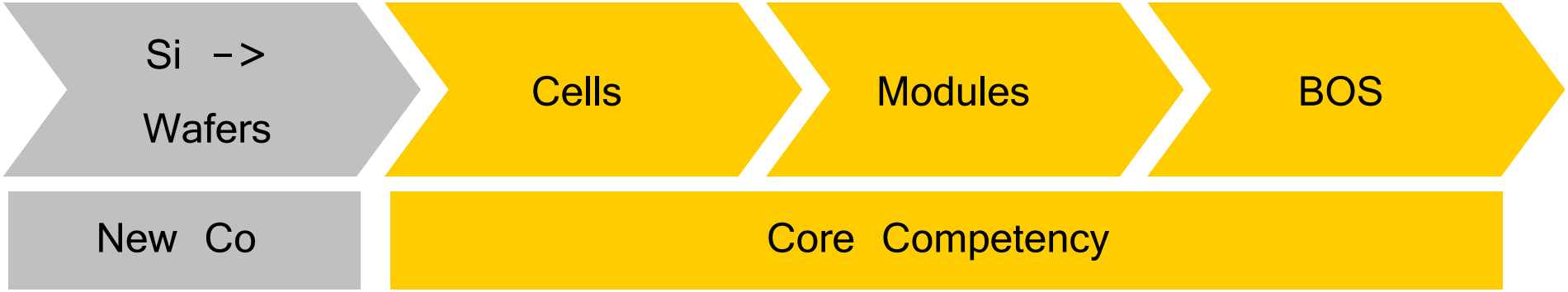
bp solar

Commercial Roof

BP Solar Facility at Frederick, MD

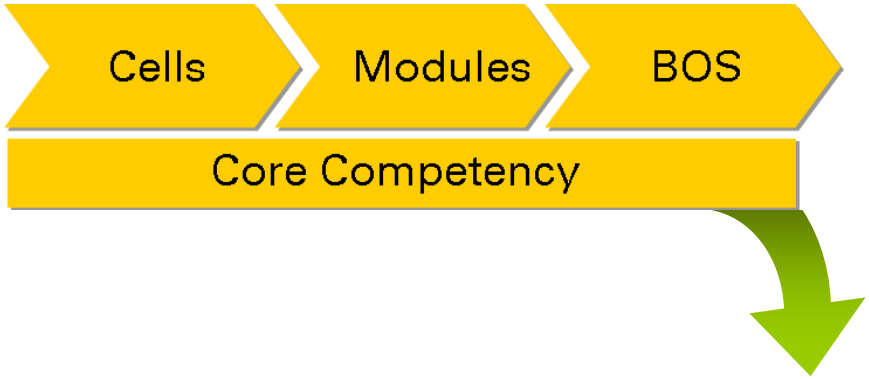
Utility Scale

Overview



BP Solar will continue to invest in key research and development activities from cells to BOS – focus to maximize energy generation and reduce cost

Overview



- Technical Depth and Breadth
  - 9 Ph.D.s, 5 M.S.s, 2 MBAs…
  - Materials, Physics, Electrical Engineering, Optical Science, Physical Chemistry, Chemical Engineering, Mechanical Engineering…

- Industry Depth and Breadth
  - Thin Film, Material Reliability, Coatings, semiconductor…
  - High volume electronics, automotive to VC due diligence…

Relationships

AE Ventures

- Bi annual meetings with AE Ventures
- Review BPS projects
- Review AE Venture's potential investments for synergies

Scanning Capabilities

- Continued attendance to key commercial and technical seninars/conferences
- Develop IP and deliver/publish technical papers

BP Solar

Continued research and development in Frederick coupled with reliability assurance and testing

Group Technology

- Bi annual meetings with Group Technology
- Review BPS projects
- Review Group Technology's projects for synergies

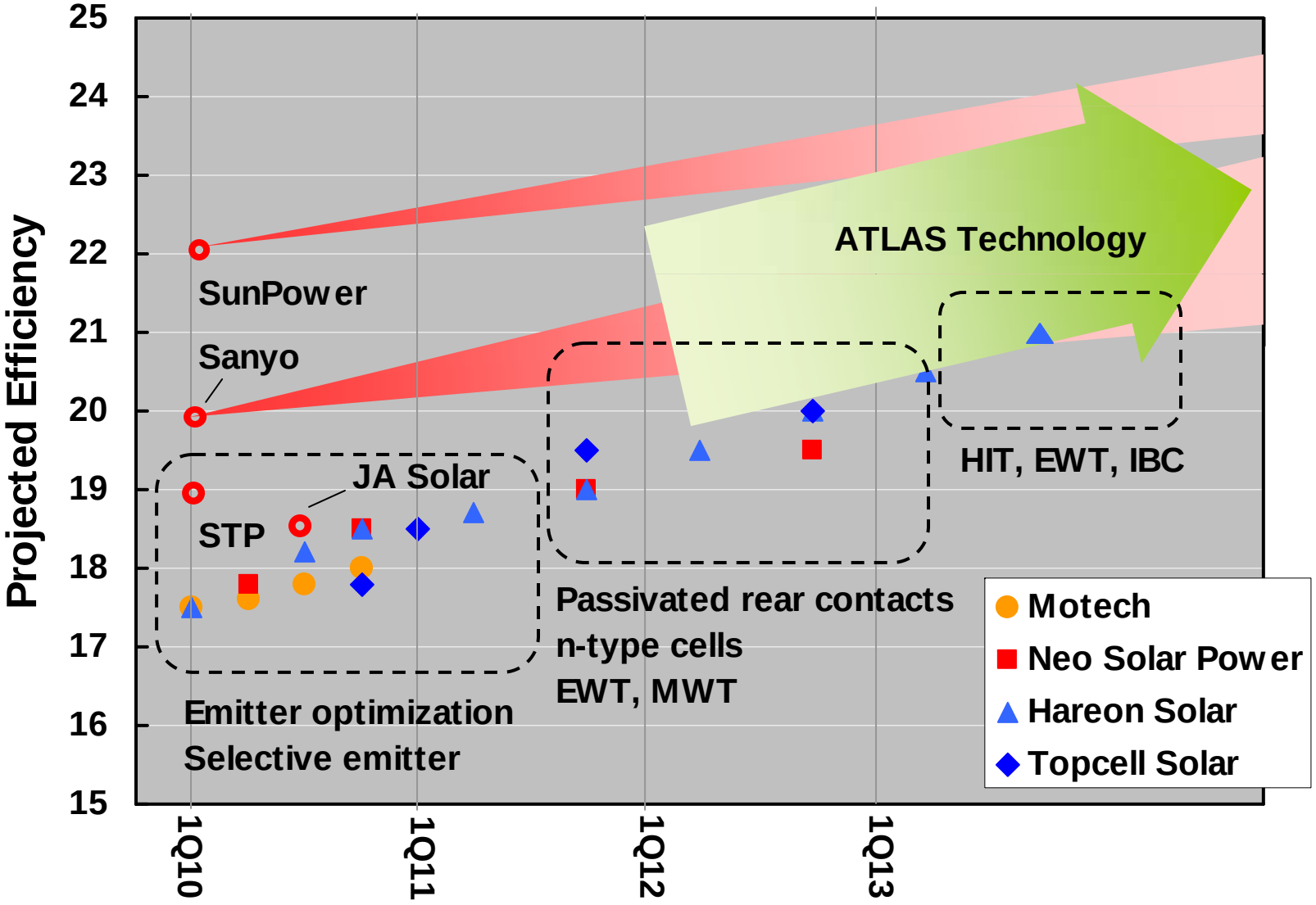
Research Programs

- California Institute of Technology (Caltech)
- Northwestern University
- Penn State University
- National Renewable Energy Laboratory (NREL)
- Brookhaven National Lab (BNL)

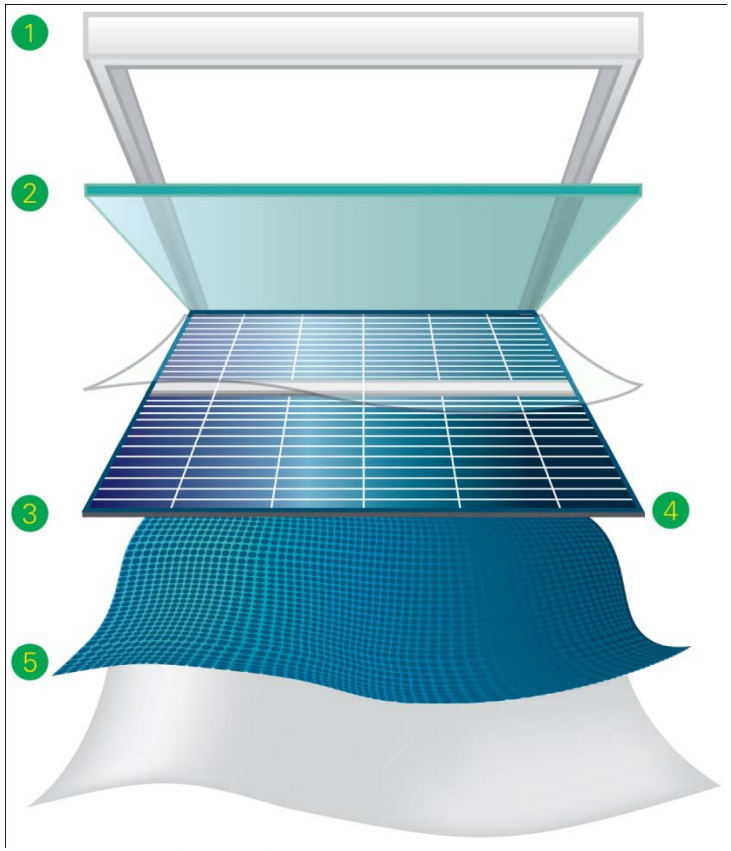
PV Technology Outlook

PV Technology	Timing	Material Availability	Toxicity	Reliability	Market Size (GW)	Module Efficiency	Manufact. $/W	Installed $/W Resid.	Installed $/W Utility
mc-Si	Current	Abundant	None	Proven	12	15%	0.65	2.70	2.00
Mono-Si	Current	Abundant	None	Proven	11	16% (21%)	0.65	2.7 (2.5)	2 (1.9)
Ribbon-Si	Current	Abundant	None	Proven	0.2	14%	>1.30	3.30	2.50
a-Si	Current	Abundant	None	Proven	0.5	6%	>1.30	4.00	3.00
a-Si/uc-Si	Starting	Abundant	None	Not est.	0.5	10%	1.00	3.70	2.50
CIGS	Starting	In	Se	Not est.	1	13%	0.65	3.00	2.10
CdTe	Current	Te	Cd	Proven	5	12%	0.65	2.90	1.60
High CPV	Starting	Abundant	As	Not est.	0.2	>25%	1.5	N/A	3
Dye-Sens.	>5 yrs	Ru	Ru	Poor	Niche	5%	TBD	TBD	TBD
Organic	>10 yrs	Abundant	None	Poor	Niche	<4%	TBD	TBD	TBD
Nano	>10 yrs	Abundant	Pb, Cd	Unknown	-	TBD	TBD	TBD	TBD
Si wire	>10 yrs	Abundant	None	Unknown	-	TBD	TBD	TBD	TBD

Cell Development Overview



Key Design Features



engineered with

InnerCool™

- 1. Robust frame
  - Rugged and durable materials form a strong, protective frame.
- 2. Anti-reflective coating
  - Darker surface lets the module absorb more sunlight than conventional modules, and produce up to 4% more energy.
- 3. Smart Electronics Design（IntegraBus & N-type junction box）
  - Increased reliability and extended product life, thanks to unique electronics design.
- 4. Improved Cell Protection
  - Our modules have the lowest average power degradation rates in the industry, thanks to using the toughest materials in our designs.
- 5. Patented thermal cooling layer
  - Unique BP Solar innovation that boosts energy output up to 3% by lowering the temperature inside the module.

2011 Module Power Roadmap
(as of Jan 2011)

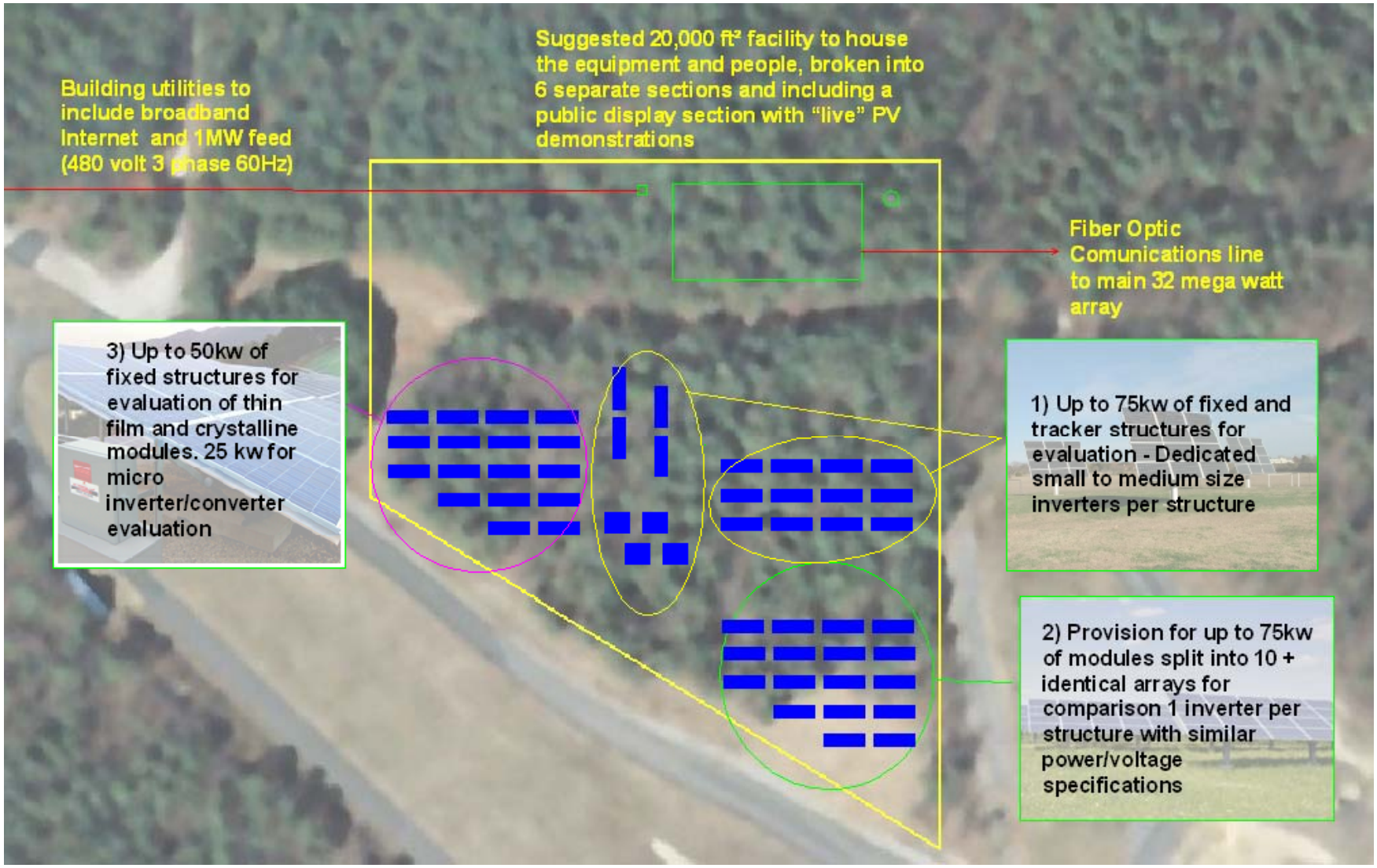
	1Q11	2Q11	3Q11	4Q11
72 cell	**M150d** • 180W • 175W • -3/+5% **M165d** • 185W • 180W • 0/+5%		**M165d** • 190W • 185W • -0/+5%	
60 cell	**P156** • 235W • 230W • 225W • -3/+5%		**P156** • 240W* • 235W • 230W • -0/+5%	
Utility	**P156** • 72/270W • 144/280W* • -5/+5W		**P156** • 72/280W • 144/290W* • -5/+5W	

*Limited volume

BNL R&D Program

- 2010 Long Island Power Authority expands into large solar plants (became the Long Island Solar Farm LISF)
- Land available on Brookhaven National Labs (BNL) property
- At 37 MWdc in size, the project represents one of the largest of its kind to ever be constructed
- BNL accepted to host the 37 MW DC array on the condition they receive some "consideration" in terms of R&D efforts
  - Phase 1 - Monitoring the large array (Phase 1)
  - Phase 2 - R&D facility with multiple sub-systems (Phase 2)
- R&D dollar consideration of ~$4.5 million for the duration of LISF

BNL R&D Concept



Reliability Program

BP Testing	Implications
Thermal cycling at **2.5 times** IEC Standards	Thermal cycles stress and crack module interconnects; failures of interconnects lead to significant loss of power
Damp heat exposure at **25% more** than IEC standards	Moisture and heat can lead to corrosion leading to significant power loss or module failure
Addition of wind simulation to IEC humidity freeze cycles	Modules experience significant flexing due to wind pressure that can cause cell cracks and lead to reduced module output or failure
Load testing **as much as twice** the IEC standard	Modules experience significant flexing due to snow loads that can cause cell cracks and lead to reduced module output or failure

Summary

"Creative innovation that enables competitive position with Safe and Reliable PV products."