Overcoming the Barriers to Achieving Large-Scale Production – A Case Study

From concept to large-scale production, one manufacturer tells the story and identifies the primary challenges and how a small amount of government support could be most helpful.

Scott Burroughs
Semprius, Inc.

August 31, 2011

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Semprius Overview / Background

Company:

- Leading developer of commercial & utility solar solutions
- Chosen by Siemens as the CPV company to partner with

Product:

- High efficiency CPV Modules and Modular Arrays
  - <$0.10 / kWh without subsidies
  - Very high capital efficiency <$0.50/W manufacturing plant
  - Scalable manufacturing and deployment

Uniqueness:

- Micro-cell technology + patented automated mfg. process

Status:

- Demonstrated high efficiency CPV module performance
- Building a 5-35MW pilot production line

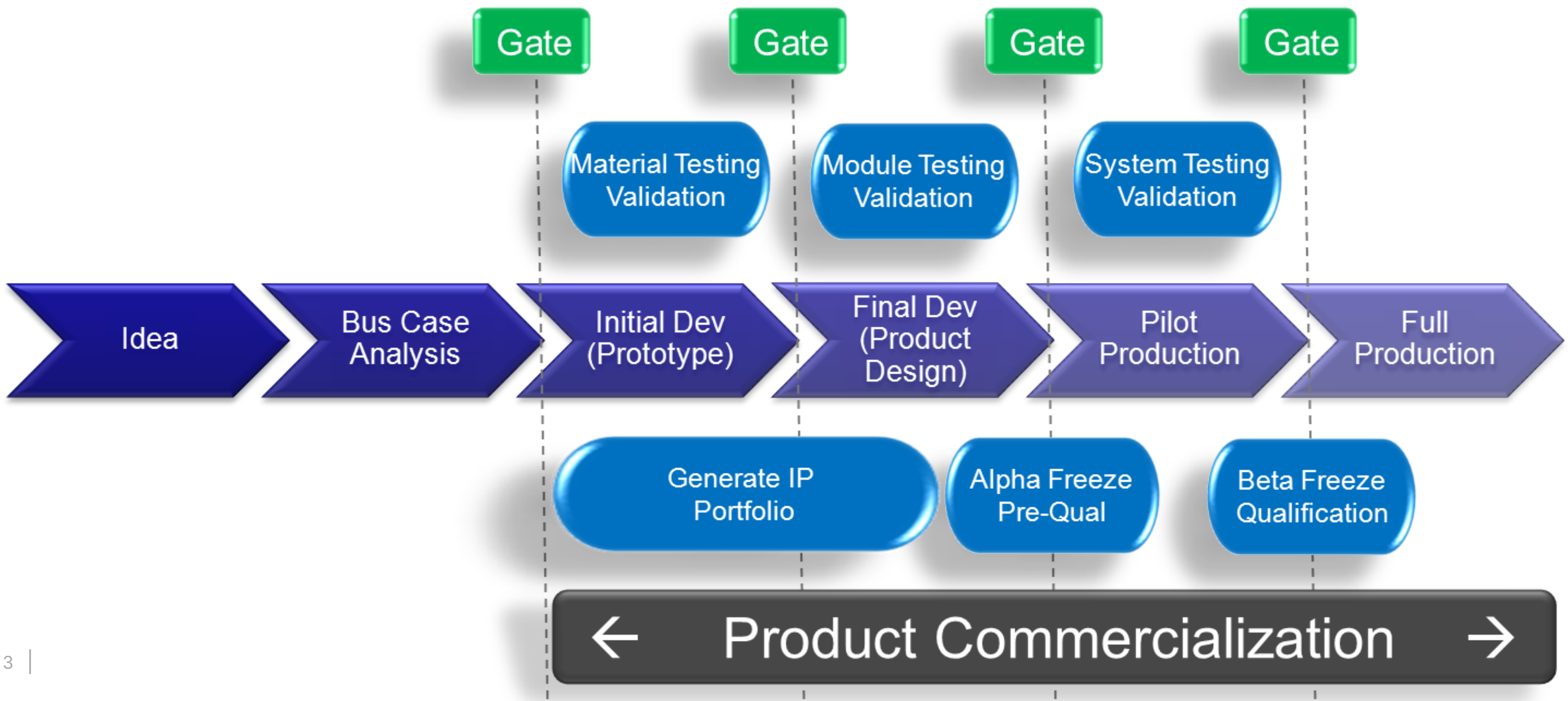
Investors:

Grants:

DOE Solar America Initiative Future Gen (2007)
DOE Pre-incubator (2009)
DOE Incubator (2010)

Semprius Case Study

- Problem:
  - Determine the most effective way to move the company from feasibility demonstration, through development, to the market place, and into high volume production (i.e. successfully through the commercialization process) with limited funding.



Semprius Case Study

- Up-Front Questions:
  - What are the customer requirements in terms of cost, performance, reliability, timing, etc.?
  - How fast should the pace toward commercialization be?
  - What barriers must be addressed prior to high volume production?
  - What validation of product performance is necessary?
  - What barriers must be addressed to ensure bankability?
  - What resources are needed to ensure success?

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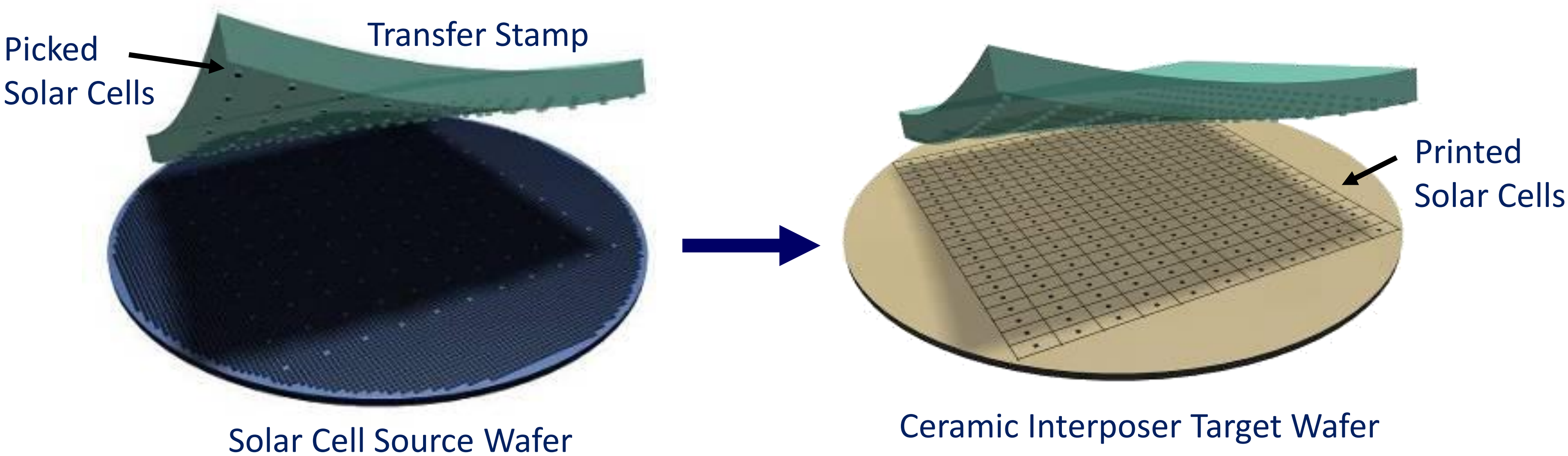
What we did and continue to do…

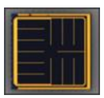
1. Start with a good idea:
   μ-transfer printing invention from UIUC†



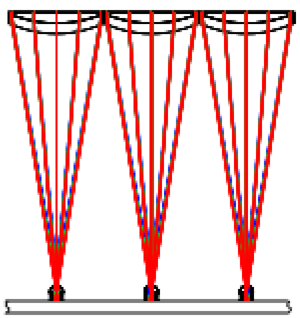
†Professor John Rogers

What we did and continue to do…

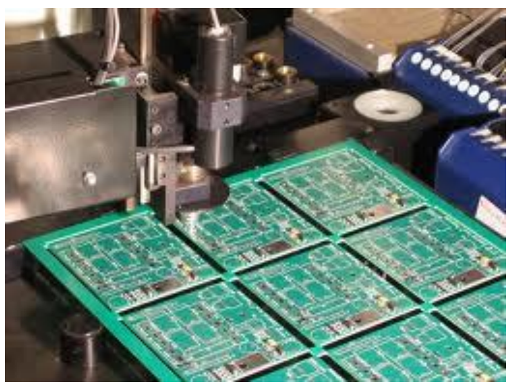
2. Build upon that idea:
Small cells, low cost high efficiency optics insensitive to tracker inaccuracies, high concentration ratio for low cost, industry standard SMT, thin module cross-section, zero cost thermal management…

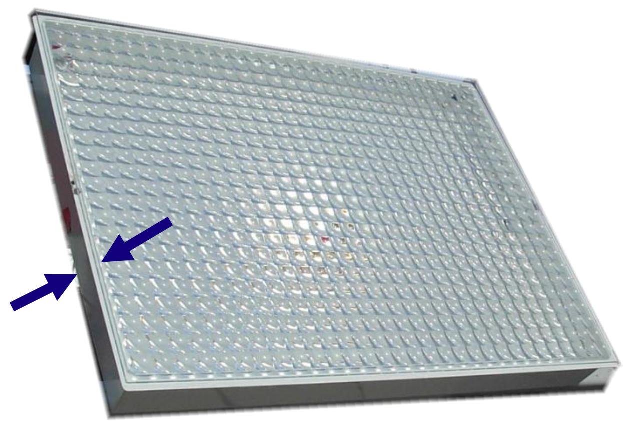


600µm



>1,100 Suns





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What we did and continue to do…

3. Design for low cost using LCOE inputs from Day 1

$$LCOE = \frac{\sum Life\ Cycle\ Costs}{Total\ Lifetime\ Energy\ Production}$$

$$LCOE = \frac{Capital\ Investment - Incentives - \sum_{n=1}^{N} \frac{Depreciation^n}{(1 + Discount\ Rate)^n} \times (Tax\ Rate) + \sum_{n=1}^{N} \frac{Operating\ Costs^n}{(1 + Discount\ Rate)^n} \times (1 - Tax\ Rate)}{\sum_{n=1}^{N} \frac{Initial\ Energy\ Production \times (1 - System\ Degradation\ Rate)^n}{(1 + Discount\ Rate)^n}}$$

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What we did and continue to do…

4. Maximize early learning from customers and from ISFOC, NREL, SNL, Fraunhofer ISE, TÜV Rheinland PTL, UL, etc.

Tucson Electric Power – A UniSource Energy Company
Chevron
Southern California Edison – An Edison International Company
Xcel Energy
SMUD – Sacramento Municipal Utility District – The Power To Do More.
APS – The Power to Make it Happen
ISFOC
Duke Energy
NREL – National Renewable Energy Laboratory
PG&E
Sandia National Laboratories
SDGE
Fraunhofer ISE
TÜV Rheinland PTL
Progress Energy
SIEMENS
Austin Energy
NV Energy
UL Underwriters Laboratories
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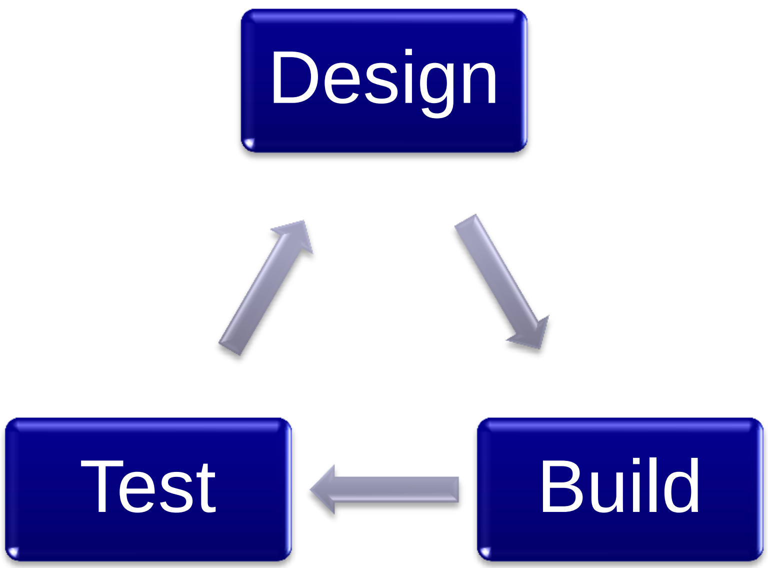
What we did and continue to do…

5. Many quick turns through R&D process

6. Continuous reliability feedback throughout the design phase

7. Early 'on-sun' testing for design feedback, to de-risk the technology, and to enhance customer's experience and comfort with the product



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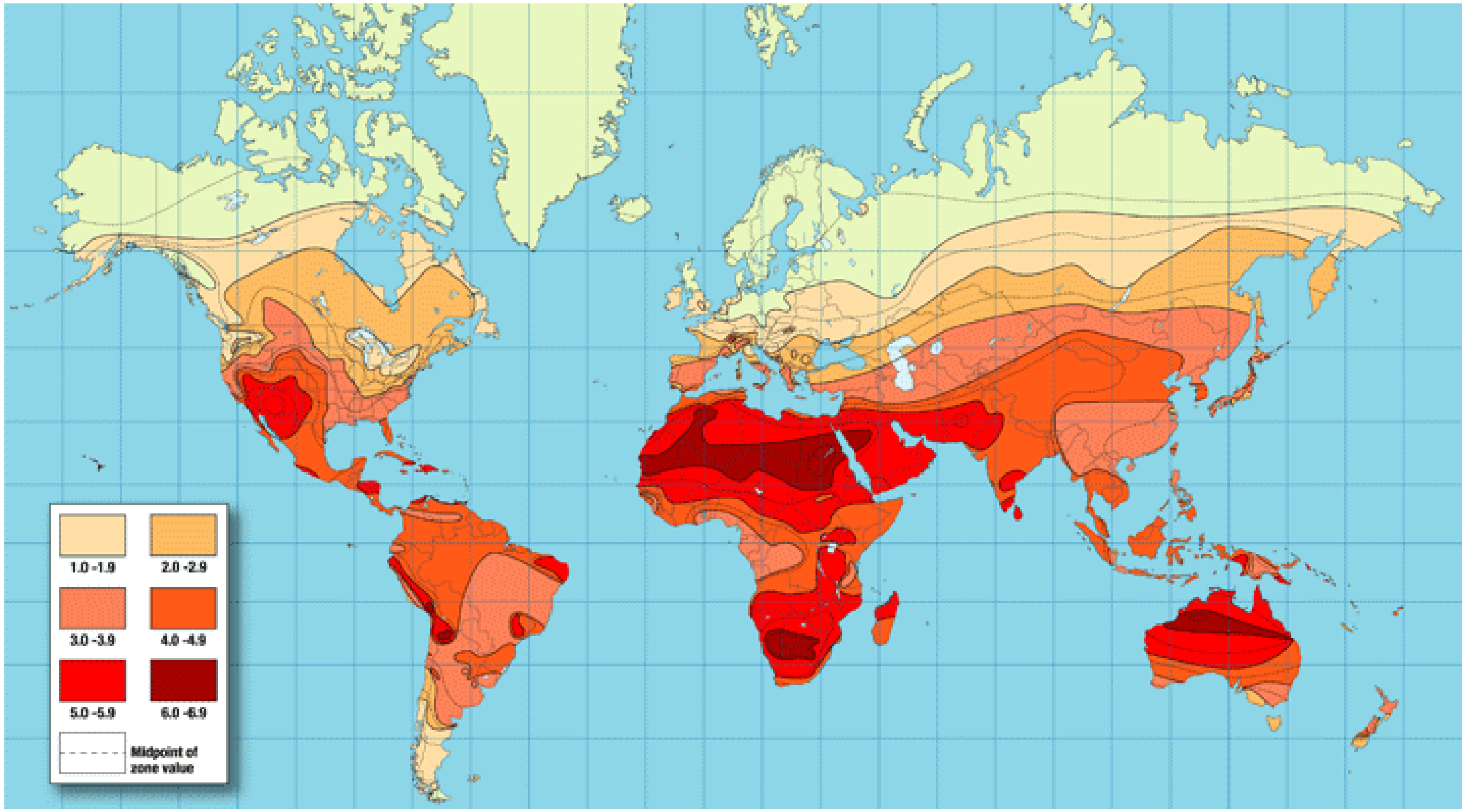
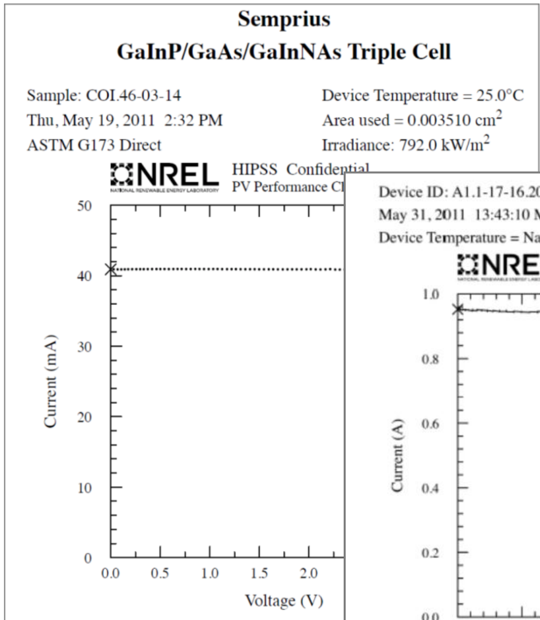
What we did and continue to do…

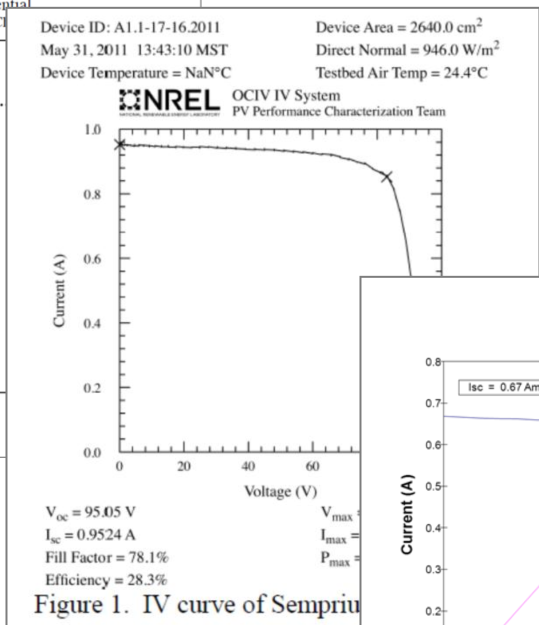
8. Install modules and RD&D systems broadly in many geographies and climates to establish small footprints with big customers

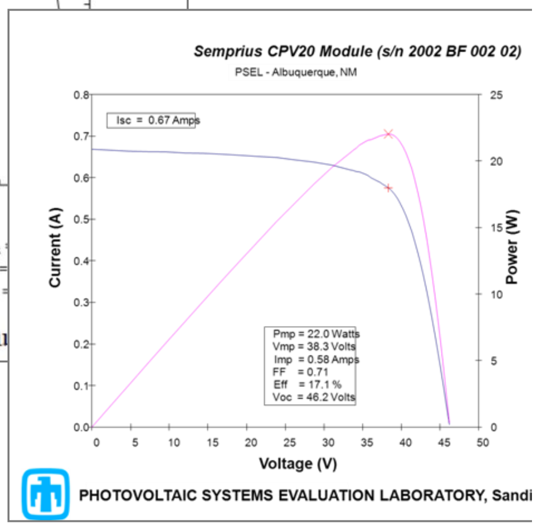


What we did and continue to do…

9. Acquire early and frequent third party certification of cell, module, and system performance







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CONTRACT INFORMATION			
Project Number	SIE100914	TÜV File Number	21215415
Manufacturer Name	Semprius, Inc.		
Manufacturer Address	4915 Prospectus Dr., Suite C Durham, North Carolina 27713		
Client Authority	Mr. Jörg Althaus		
Email	Joerg.Althaus@de.tuv.com	Phone: +49 221 806 2087	Fax: +49 221 806 1350
Model under test	CPV 100		
Test Program	Engineering Evaluation – System and Tracker verification		
REPORT APPROVAL			
Report Number	R-SIE100914		
Report Date	10/30/2010		
Prepared by:	Kent Farnsworth	[signature]	
Approved by:	Todd Arends	Todd W. Arends	

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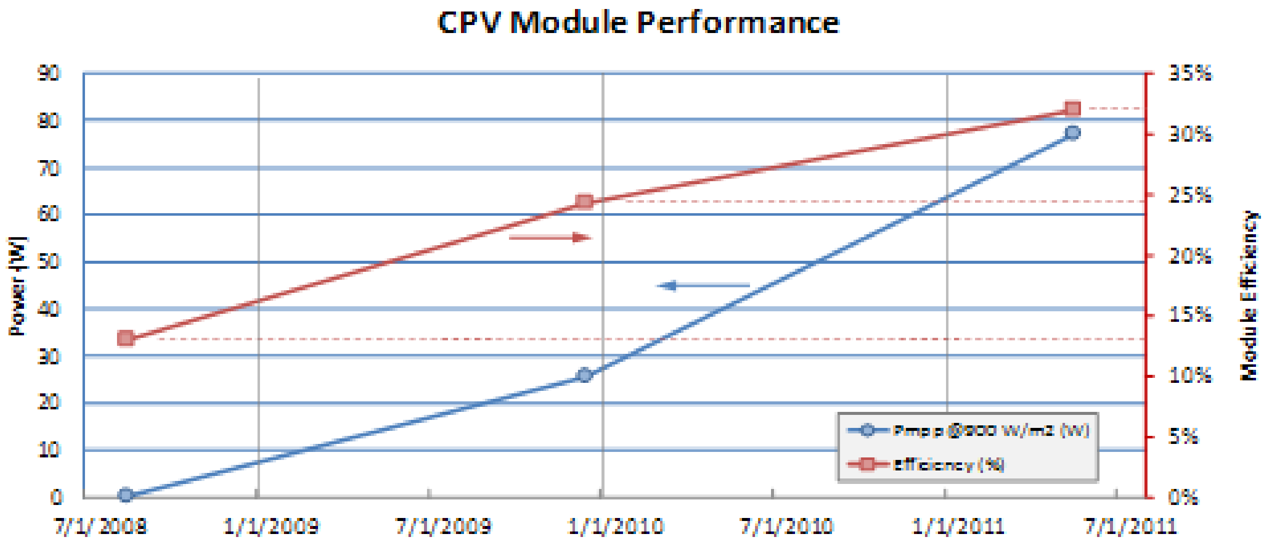
CONCLUSION

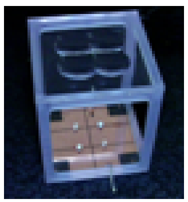
The tracking accuracy of the Siemens tracker met the manufacturer's specification of +/-0.2 degrees. The system performance rating, based on ASTM E 2527, was 1029.2 W DC at Performance Test Conditions (PTC), which exceeded the specified rating of 960 W DC from the manufacturer.

What we did and continue to do…

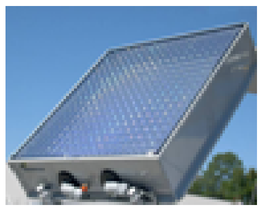
10. Share progress with investors to ensure continued funding

Semprius CPV Module Evolution

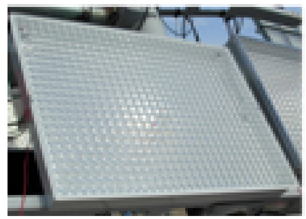




1-Junction cells



2-Junction cells



3-Junction cells

From feasibility demonstration to state-of-the-art performance in <3 years

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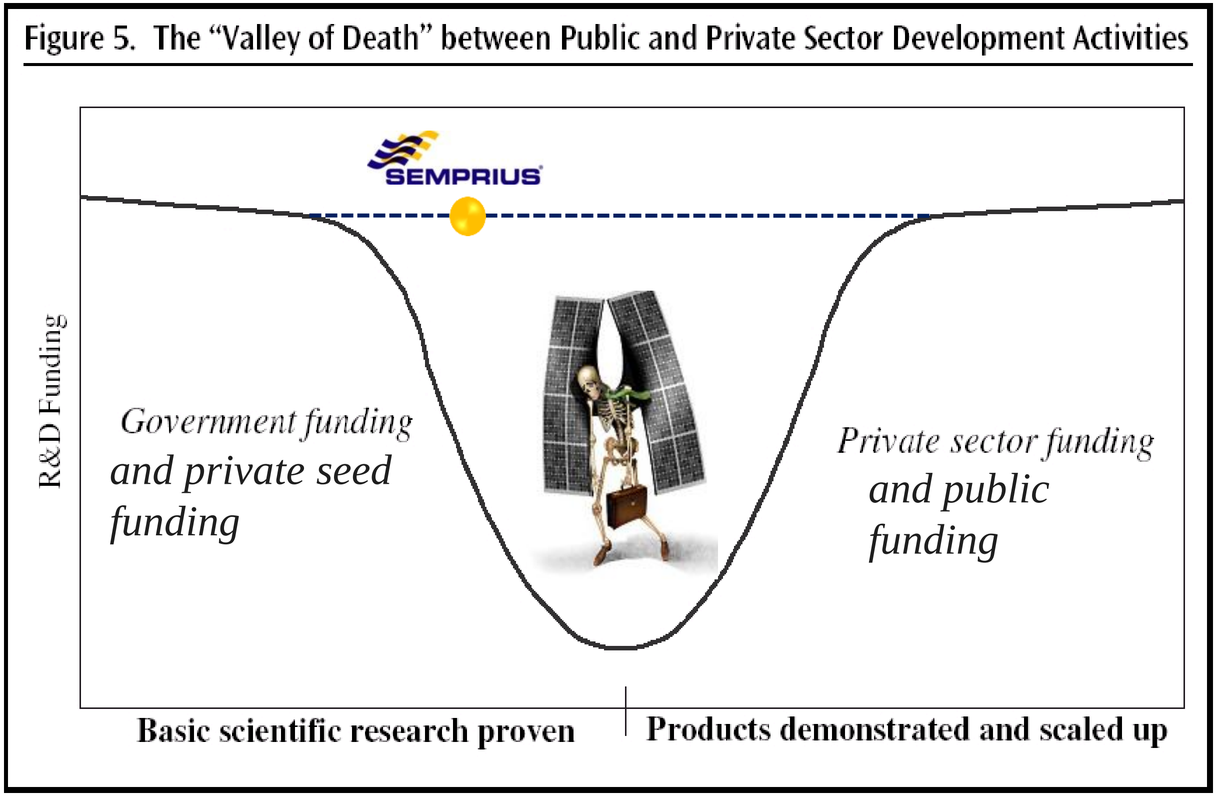
What we did and continue to do…

11. Consider utility customer's requirement for long term on-sun data; Requires patient investors, careful management of cash, and a 'Goldilocks' pace that is not too fast, not too slow, just right since utilities customers are naturally conservative, careful, and risk averse.

What we did and continue to do…

12. Need interim injections of funding at key phases of the commercialization process; Siemens strategic investment, NC incentives, VC funding, and DOE funding; Especially true prior to and while traversing the "Valley of Death".



Source: Electric Power Research Institute (EPRI)

Newsweek

DOE's SUNPATH program may in-part bridge the Valley of Death

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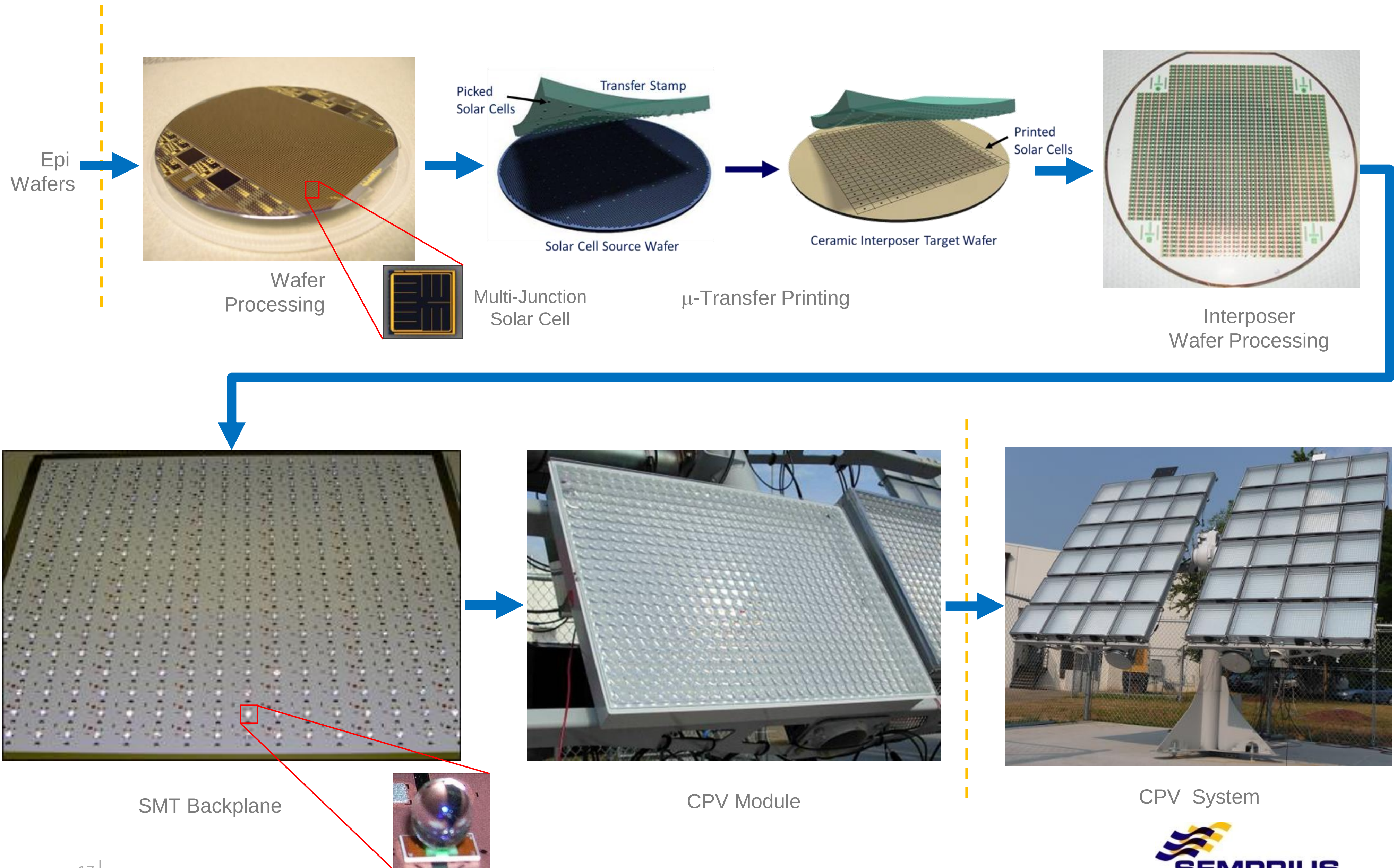
What we did and continue to do…

13. Find good partners early on – Siemens Energy

The Siemens partnership helps to address the bankability issue

The results…

Overview of Semprius CPV Approach



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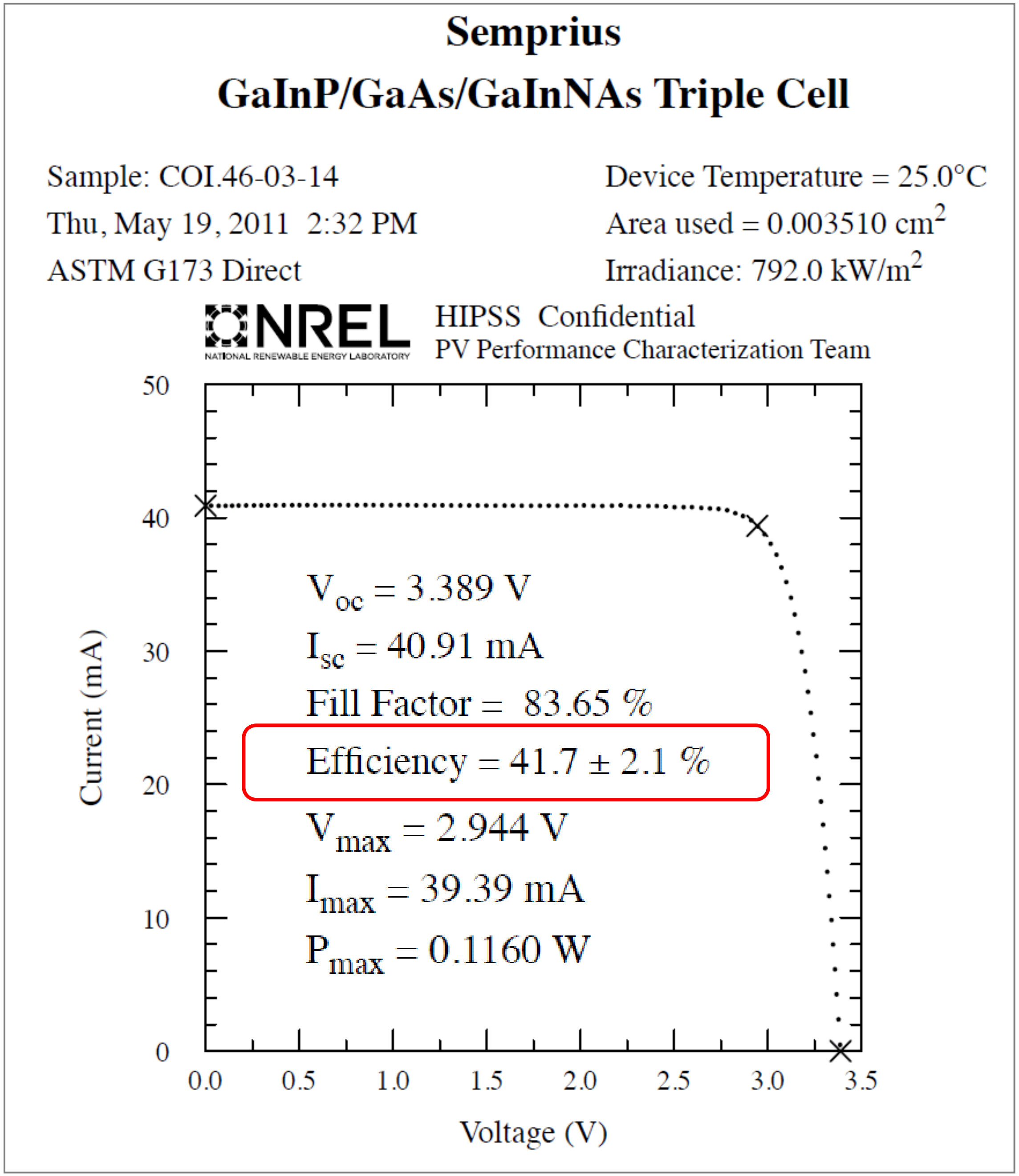
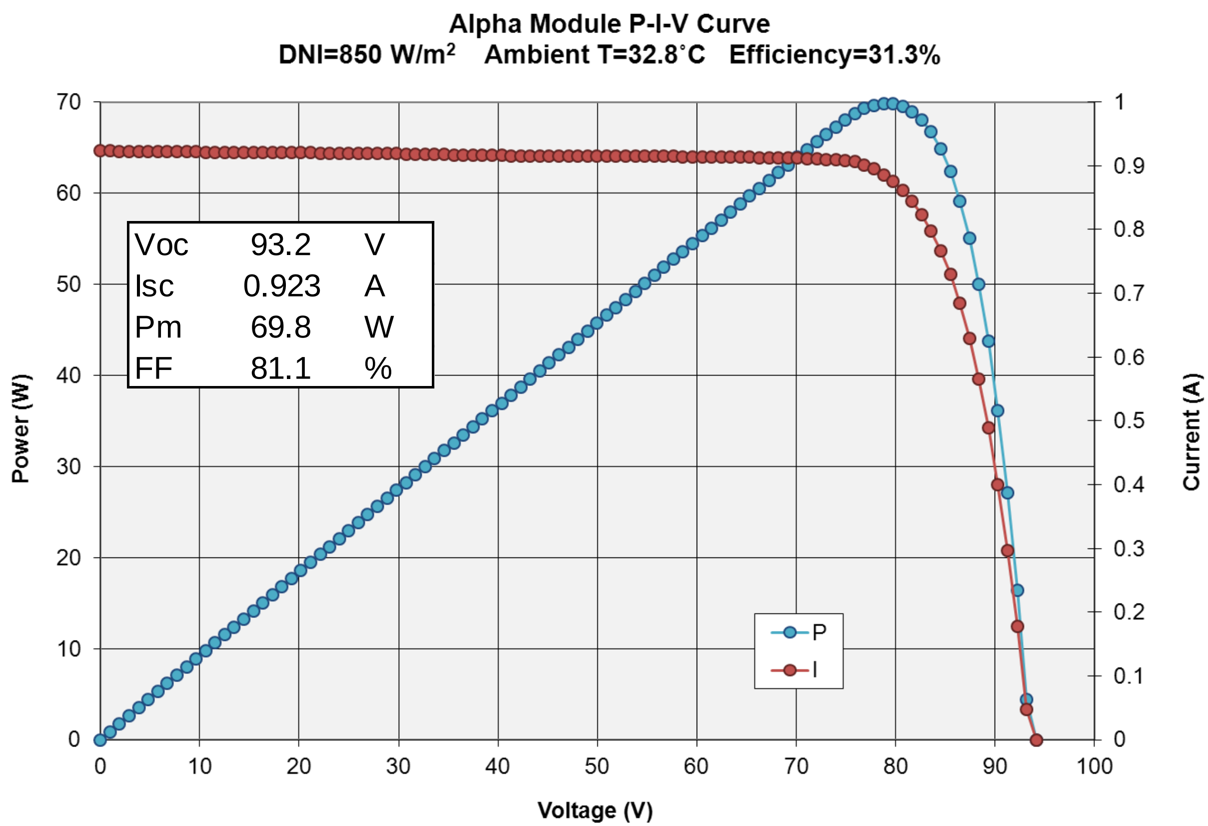
41.7% Cell Efficiency as Measured by NREL



Alpha Module Test Results with 3-J Solar Cells



Module Efficiency > 31%

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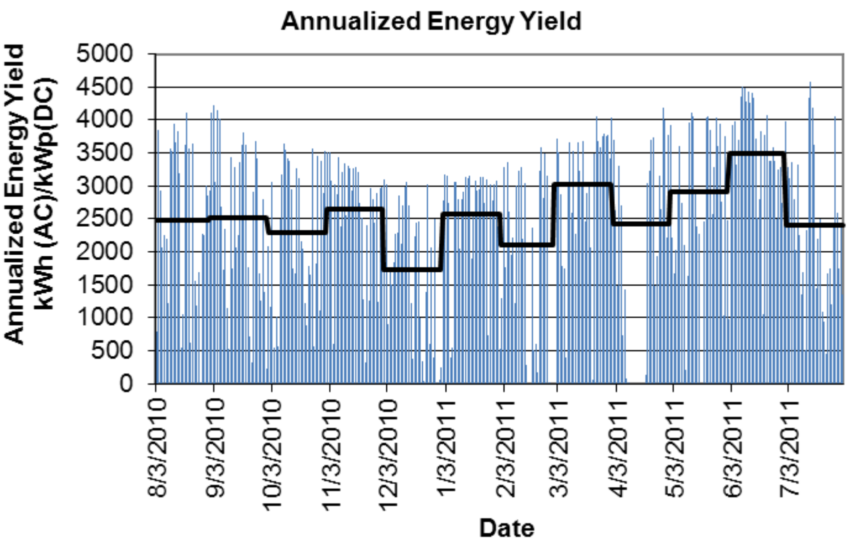
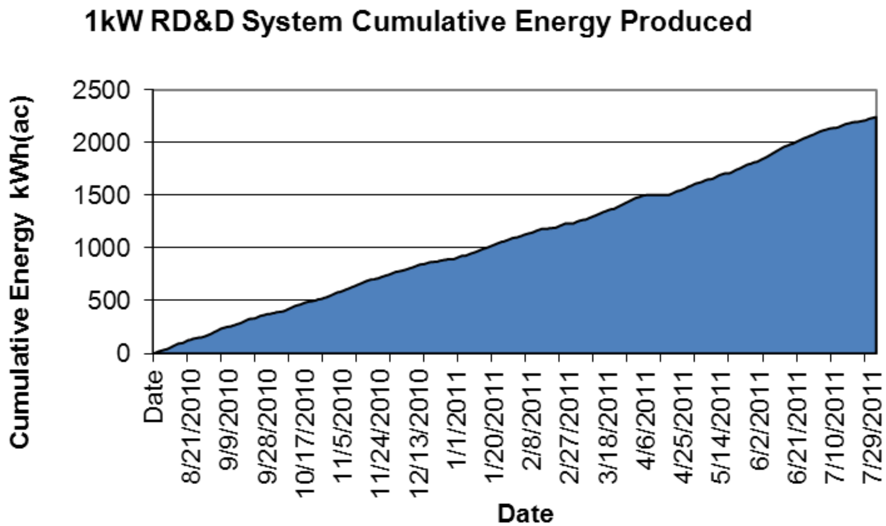
1 kW RD&D System at Tucson Electric Power

- Installed in August 2010 in Tucson, AZ
- Semprius engineering prototype modules
- 2 axis tracker from Siemens
- Tracker array frame from Cosma Intl.
- Weather and DAQ system included

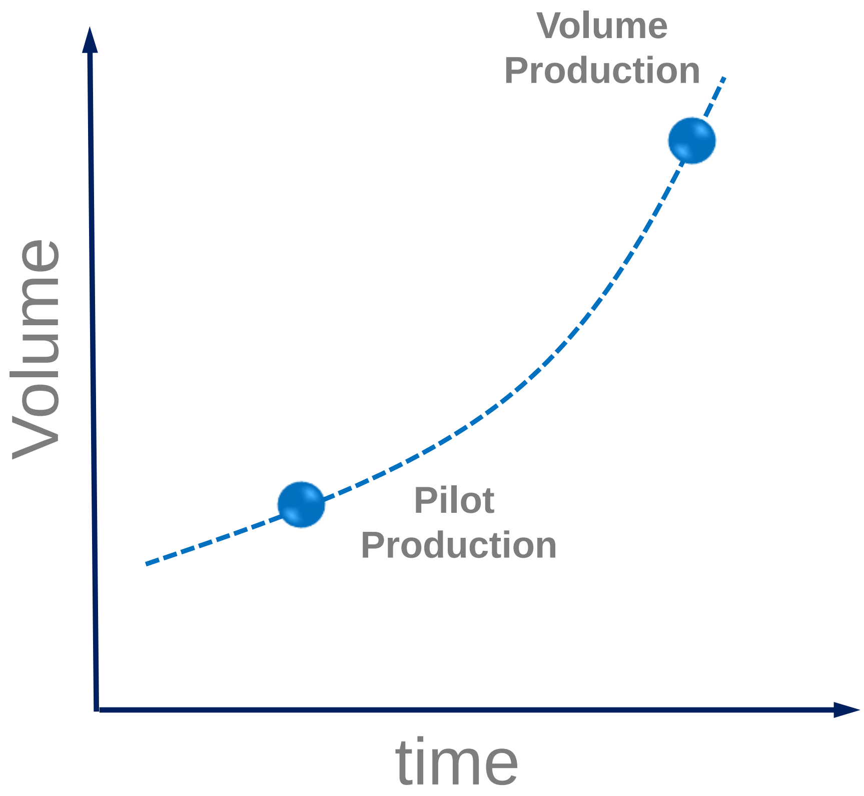
Tucson Electric Power

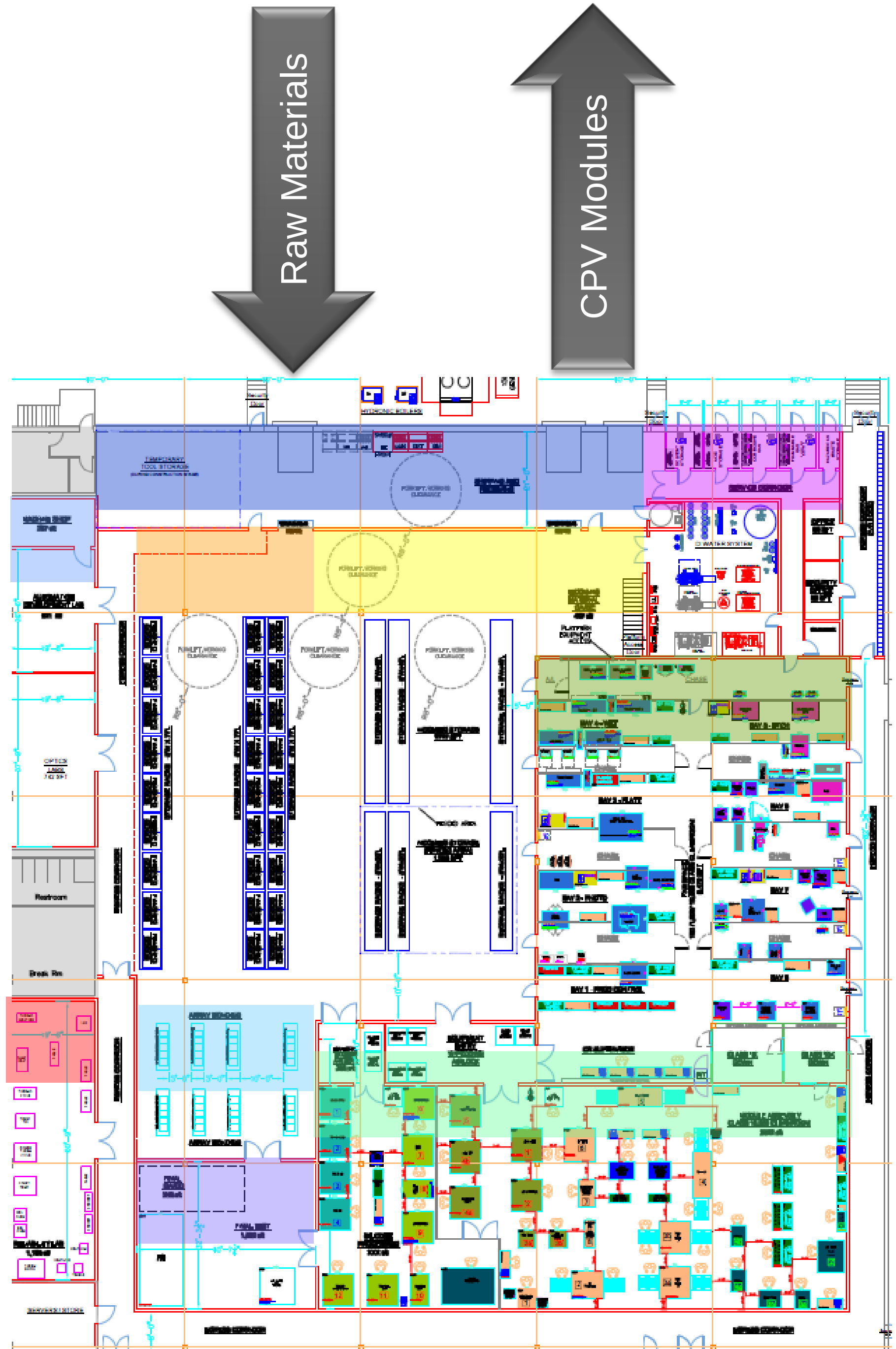
A UniSource Energy Company





Pilot Production Line





Next steps…

Focus on:

- Refining processes
- Establishing pilot line
- Qualifying pilot line
- Ensuring module reliability
- System testing & verification
- Winning customers
- Installing our 1st MW CPV plant
- Ramping to high volume production
- Developing improved next generation designs
- Additional fund raising

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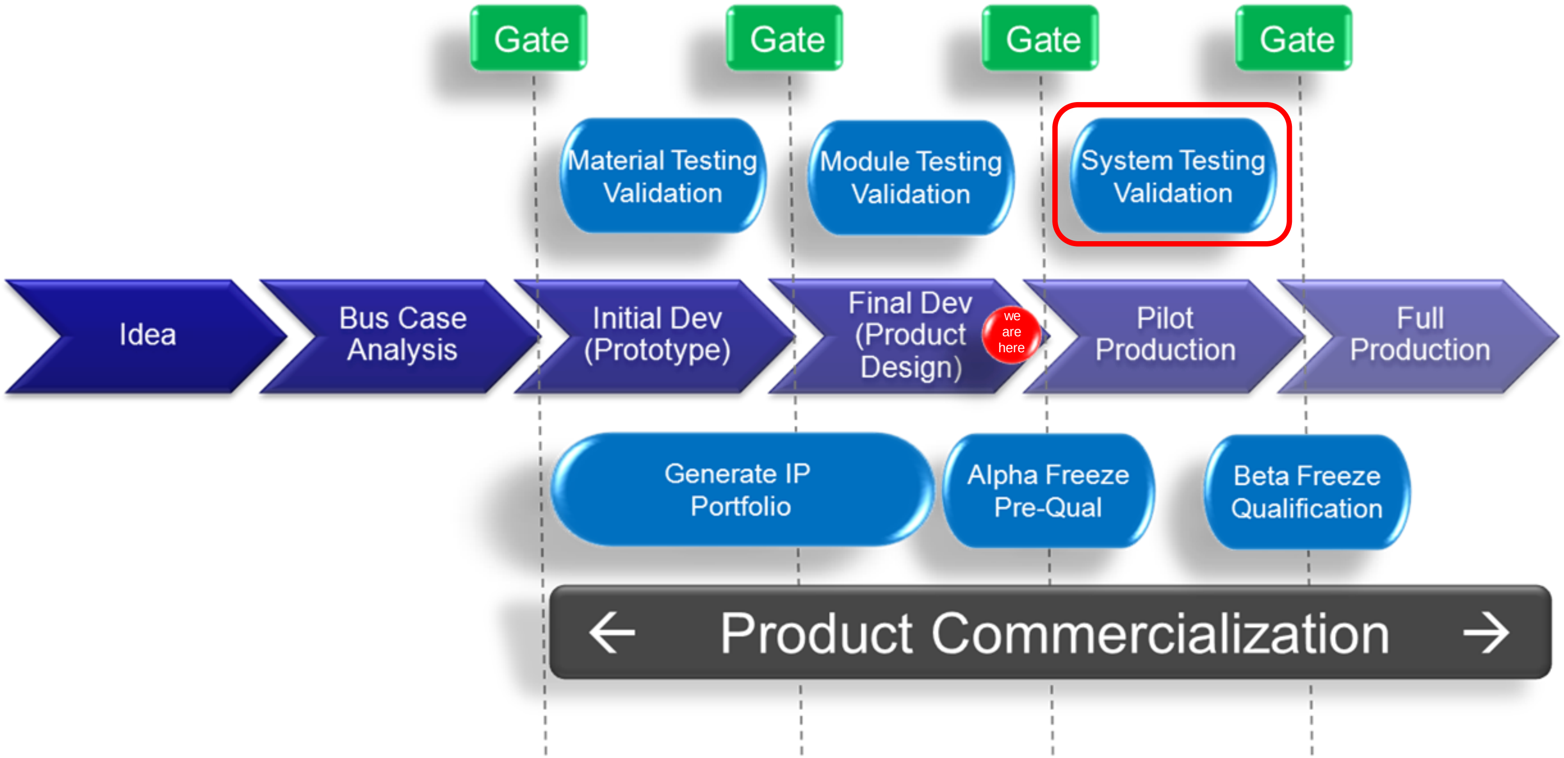
Need for Regional Test Centers (RTCs)



System testing and validation can start out small, but ultimately must be done at the 100kW – 1MW level to capture 'real' system issues

System costs for such testing and validation will exceed $1M

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Principle Organizations for CPV Testing/Validation

- Solar Cell
  - NREL (Golden, CO)
  - Fraunhofer ISE (Freiburg, Germany)
- Module
  - NREL (Golden, CO)
  - SNL (Albuquerque, NM)
  - Fraunhofer ISE (Freiburg, Germany)
  - TÜV Rheinland PTL (Tempe, AZ)
- System
  - ISFOC
  - SolarTAC [Technology Acceleration Center] (Aurora, CO)
  - UA TechPark (Tucson, AZ)

The above organizations generally require payment for their services.

It is important that funding be available to finance large scale testing & validation programs.

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Module & System Testing/Validation Needs

- High DNI location for CPV testing
- High insolation to quickly accumulate kWh
- Access to weather data (DNI, GNI, CSR, ambient temperature, wind speed & direction, rainfall, dew point, video cloud cover, etc.)
- Access to individual DC string data (Voc, Isc, Pm) as well as individual inverter AC output and module temperature through an on-line data acquisition system.
- On-site support personnel for troubleshooting, operations & maintenance, data monitoring, experiments, etc.
- Availability of curve tracers, oscilloscopes, spectrometers, and other test equipment.
- Funding to offset the installed cost, operation costs, and monitoring/analysis costs.

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scott.burroughs@semprius.com