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.

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Semprius, Inc.

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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?
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
What we did and continue to do…

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

\[
LCOE = \frac{\sum \text{Life Cycle Costs}}{\text{Total Lifetime Energy Production}}
\]

\[
LCOE = \frac{\text{Capital Investment} - \text{Incentives} - \sum_{n=1}^{N} \frac{\text{Depreciation}^n}{(1 + \text{Discount Rate})^n} \times (\text{Tax Rate}) + \sum_{n=1}^{N} \frac{\text{Operating Costs}^n}{(1 + \text{Discount Rate})^n} \times (1 - \text{Tax Rate})}{\sum_{n=1}^{N} \frac{\text{Initial Energy Production} \times (1 - \text{System Degradation Rate})^n}{(1 + \text{Discount Rate})^n}}
\]
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.
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
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
What we did and continue to do...

10. Share progress with investors to ensure continued funding
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”.

**Figure 5. The “Valley of Death” between Public and Private Sector Development Activities**

- **Government funding and private seed funding**
- **Private sector funding and public funding**

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

Epi Wafers

Wafer Processing

Multi-Junction Solar Cell

μ-Transfer Printing

Interposer Wafer Processing

SMT Backplane

CPV Module

CPV System
41.7% Cell Efficiency as Measured by NREL

GaInP/GaAs/GaInNAs Triple Cell

Sample: COI.46-03-14
Thu, May 19, 2011 2:32 PM
ASTM G173 Direct

Device Temperature = 25.0°C
Area used = 0.003510 cm²
Irradiance: 792.0 kW/m²

NREL HIPSS Confidential PV Performance Characterization Team

Efficiency = 41.7 ± 2.1 %

V_oce = 3.389 V
I_sc = 40.91 mA
Fill Factor = 83.65 %
V_max = 2.944 V
I_max = 39.39 mA
P_max = 0.1160 W
Module Efficiency > 31%
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
Pilot Production Line

Volume Production

Volume

Pilot Production

time
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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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.
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.
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.