CALYXO CdTe
Excellent yield per $W_p$ of the PV technologies

Dr. Claudius Neumann
Head of Product Management, Calyxo GmbH
VOTUM TF Workshop, Prague, May 13th 2010
PURPOSE OF THIS PRESENTATION

… To introduce Calyxo‘s successful development as photovoltaic module manufacturer

… To provide data about Calyxo‘s module properties, design and application

… To inform about the favorable environmental aspects of the CdTe module technology
OUTLINE OF THE PRESENTATION

1. CALYXO COMPANY DEVELOPMENT

2. THE CALYXO CdTe PHOTOVOLTAIC MODULE

3. SYSTEM TECHNOLOGY WITH CALYXO CX1

4. ENVIRONMENTAL ASPECTS OF THE CALYXO CdTe PRODUCT
Calyxo has developed successfully since 2004.

Solar Fields starts with the development of its unique CdTe technology in June 2004.

Foundation of Calyxo GmbH and exclusive license contract with Solar Fields.

Joint Venture with Solar Fields and foundation of Calyxo USA INC.

Expansion of capacity up to 25MWp.

Laying of the cornerstone for the second production line (capacity of 110 MWp).

IEC Certification.

Module efficiency > 9% in serial production.

Ramp-Up of 110 MWp-production line.

Expansion of capacity up to 25MWp.

Module efficiency > 9% in serial production.

Ramp-Up of 110 MWp-production line.
MODULE EFFICIENCY INCREASED STEEPLY OVER THE LAST 11 MONTHS

Module efficiency development

Efficiency distribution January 2009

Efficiency distribution April 2010

Focus 2010 shifting and tightening distribution
PRODUCTION OUTPUT HAS GROWN STEADILY SINCE EARLY SUMMER 2009

Production volumes Calyxo

I.O. Modules out per month
Accum. Power

Planned line upgrade
PRODUCTION CAPACITY WILL RISE WITH FULL LINE EXTENSION OF LA 1 AND LB 1

LB1
Office space 500m²
Utility wing 1.000m²
production 11.600m²
storage 3.800m²
delivery

2011
LB1 – 110MWp
LA1 – 25MWp

Total Fläche:
17.600m²
storage 3.800m²
production 11.600m²
Utility wing 1.000m²
Office space 500m²

2011
CALYXO FOCUSES ON INDUSTRIAL ROOFTOP AND UTILITY FREE FIELD

Market Segment Overview

Utility
- Large power plants (>1 MW)
- Utility or electricity wholesale market as customer

Commercial / Industrial
- Often >100 kW installations
- Professional customers

Residential
- Small and very small installations (<10kW)
- Mainly Homeowners
- Area constraint

Off-Grid
- Varying system sizes
- Varying customer types

Relative Market share 2006 → 2013
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CALYXO MODULES ARE MANUFACTURED IN A SUPERSTRATE PROCESS

Input: TCO Coated Glass

- Laser Scribing Datamatrix Code
- Deposition (CdS and CdTe)
- Laser Scribing TCO
- Handling
- Laser Scribing Semiconductor
- Chemical handling

- Copper strip Application
- Edge Deletion
- Back Contact Scribing
- Back Contact Deposition

- Stacking
- Laminating
- Cleaning and Junction box
- Module Tester

- Washing Front Glass
- EVA cutting
- Packing
- Labeling
- Visual Inspection
- High Pot Test
CURRENTLY OFFERED CALYXO MODULES ACHIEVE A POWER UP TO 65 WATT

Calyxo Cell Structure

Performance at standard test conditions (STC: 1000 W/m², 25°C, AM 1.5 spectrum)

<table>
<thead>
<tr>
<th>Product Name</th>
<th>CX 55</th>
<th>CX 57</th>
<th>CX 60</th>
<th>CX 62</th>
<th>CX 65</th>
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<tbody>
<tr>
<td>$P_{\text{max}}$ [W]</td>
<td>55</td>
<td>57.5</td>
<td>60</td>
<td>62.5</td>
<td>65</td>
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<tr>
<td>$I_{\text{sc}}$ [A]</td>
<td>1.15</td>
<td>1.15</td>
<td>1.15</td>
<td>1.16</td>
<td>1.16</td>
</tr>
<tr>
<td>$V_{\text{oc}}$ [V]</td>
<td>86.9</td>
<td>87.9</td>
<td>88.9</td>
<td>89.8</td>
<td>90.7</td>
</tr>
<tr>
<td>$I_{\text{mp}}$ [A]</td>
<td>0.93</td>
<td>0.95</td>
<td>0.96</td>
<td>0.97</td>
<td>0.99</td>
</tr>
<tr>
<td>$V_{\text{mp}}$ [V]</td>
<td>60.7</td>
<td>62.3</td>
<td>63.9</td>
<td>65.5</td>
<td>67.2</td>
</tr>
</tbody>
</table>
THE BLACK CALYXO CX 1 MODULE MEASURES 1.20 x 0.60 m
### Certification

- IEC 61646; IEC 61730 Application Class A; UL 1703 (pending);

### Warranty Statement

<table>
<thead>
<tr>
<th>Material and workmanship</th>
<th>Module performance</th>
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<tbody>
<tr>
<td>2 years</td>
<td>10 years</td>
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<tr>
<td>Upgrade to 5 years</td>
<td>Decrease of module power by more than 10 percent below initial value</td>
</tr>
<tr>
<td>in case of plant registration and access to monitoring data for Calyxo</td>
<td>20 years</td>
</tr>
<tr>
<td></td>
<td>Decrease of module power by more than 20 percent below initial value</td>
</tr>
</tbody>
</table>

**Warranty Statement**

- Module performance 20 years
- Decrease of module power by more than 20 percent below initial value
THE MODULE POSSESSES A FAVORABLE TEMPERATURE BEHAVIOR

Measurement procedure for indoor determination of $T_{\text{coeff.}}$

- Three temperature sensors on module backside
- Heating of module to 80°C and determination of electric performance during cooling with class A HALM sun simulator
- Irradiance at 200 W/m² and 1000 W/m²

<table>
<thead>
<tr>
<th>Temperature coefficient [%/K]</th>
<th>Indoor 200 W/m²</th>
<th>Indoor 1000 W/m²</th>
<th>Outdoor</th>
<th>Data sheet</th>
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</thead>
<tbody>
<tr>
<td>$P_{\text{max}}$</td>
<td>-0.22</td>
<td>-0.28</td>
<td>-0.23</td>
<td>-0.25</td>
</tr>
<tr>
<td>$I_{\text{sc}}$</td>
<td>0.06</td>
<td>0.02</td>
<td>-</td>
<td>0.02</td>
</tr>
<tr>
<td>$U_{\text{oc}}$</td>
<td>-0.38</td>
<td>-0.27</td>
<td>-0.22</td>
<td>-0.24</td>
</tr>
<tr>
<td>$I_{\text{mpp}}$</td>
<td>0.12</td>
<td>0.02</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>$U_{\text{mpp}}$</td>
<td>-0.33</td>
<td>-0.29</td>
<td>-0.26</td>
<td>-0.27</td>
</tr>
</tbody>
</table>

Data sheet
THE MODULE PERFORMANCE IS ENHANCED AT LOW IRRADIATION

Determination of performance at low irradiance

- Regular measurement of Calyxo modules with class A HALM sun simulator
- Cross check with reference of outdoor measurements
- Comparison of CX47 module:
  - Indoor measurement under IEC conditions
  - Subsequent determination of outdoor performance on tracker system

→ Indoor measurements show an efficiency decay at 300 W/m² and lower irradiance
→ The module efficiency increases at low irradiance during outdoor measurement in contrast to indoor experiments
CALYXO WILL TOP EFFICIENCIES BEYOND 9% IN 2010

### Measures

**Step 1 – Optimization of current product**
- Process stabilization
- Further improvement of layer homogeneity

**Step 2 - Further device development**
- Optimization of back contact
- Increased CdS transparency

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Q4/Q1</td>
<td>&gt;7,4%</td>
<td>8,0%</td>
<td>8,5%</td>
<td>8,8%</td>
<td>9,3%</td>
<td>10,0%</td>
<td>10,5%</td>
<td>11,2%</td>
<td>12,0%</td>
</tr>
<tr>
<td>Best module</td>
<td>10,4% in Q2 2010 achieved</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With light soaking</td>
<td>0,3 – 0,4% efficiency increase expected!</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
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### Back current tolerance and required measures

- Testing in accordance with DIN EN 61730-2 with test value equal to 135% of rated value
- Testing of Calyxo module during IEC certification process and in additional regular quality checks
- Further tests will enable higher reverse current loads

| → Maximum permissible current of 3.0A |
| → No more than four strings connected in parallel without fusing |
| → Strings can be fused with string fuses |
| → String diodes are recommended by Calyxo (see above mentioned connection scheme) |
| → Positioning of diodes and fuses in generator connection boxes requires extra generator connection boxes and additional wiring, which in turn can increase BOS cost |

**String diode connection scheme**
Requirements for DC/AC converter

- Grounded negative pole is required in order to avoid module damage by TCO delamination
- Grounded negative pole renders exclusively positive voltages which require a transformer or inductor in order to induce the negative half wave prior to grid feed-in

→ Only inverters with galvanic isolation and with grounded negative pole are approved
INDUSTRY STANDARD MOUNTING SYSTEMS CAN BE APPLIED

Clamping position
Glass overlay
Spot fitting
Line support
Insertion system

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Spot fitting
Line support
Insertion system
## Test System description

### Project description
- **Location**: Thalheim (Bitterfeld-Wolfen)
- **Installation type**: Outdoors, on stands
- **System size**: 6.18 kWp
- **Date of installation**: April 29th, 2009

### System details
- **Module type**: CX42, CX40
- **Number of modules**: 150
- **Mounting system**: Schletter FS5
- **Inclination of stands**: 30°
- **Orientation**: 0° south

### Inverter & monitoring system
- **Manufacturer / type**: SMA / Sunny Boy 3000
- **Maximum DC Input**: 3,200 W
- **MPP window**: 268 – 480 V
- **Modules per string**: 6
- **Parallel stings**: Inverter 1: 3 x 4
  Inverter 2: 2 x 4 + 1 x 5
- **Data logger / sensor**: SMA Sunny Web Box / 2 x SMA Sunny Sensor Boxes

### Graph
- **Specific Yield [kWh/kWp]**
  - **CX42 System**
  - **CX42 Simulation**
  - **CX40 System**
  - **CX40 Simulation**

**Note**: Modules partially covered by snow.
**REFERENCE SYSTEM „ALICE SPRINGS“ IN HIGH TEMPERATURE ENVIRONMENT**

**Test System description**

<table>
<thead>
<tr>
<th>Project description</th>
<th></th>
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<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Alice Springs (Australia)</td>
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<tr>
<td><strong>Installation type</strong></td>
<td>Outdoors, on stands</td>
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<tr>
<td><strong>System size</strong></td>
<td>5.4 kWp</td>
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<td><strong>Date of installation</strong></td>
<td>March 8th, 2010</td>
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<table>
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<th>System details</th>
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<tbody>
<tr>
<td><strong>Module type</strong></td>
<td>CX 50</td>
</tr>
<tr>
<td><strong>Number of modules</strong></td>
<td>108</td>
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<tr>
<td><strong>Mounting system</strong></td>
<td>Special construction, Schletter Eco 6</td>
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<tr>
<td><strong>Inclination of stands</strong></td>
<td>30°</td>
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<tr>
<td><strong>Orientation</strong></td>
<td>180° North</td>
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<table>
<thead>
<tr>
<th>Inverter &amp; monitoring system</th>
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</thead>
<tbody>
<tr>
<td><strong>Manufacturer / type</strong></td>
<td>SMA / SMC 6000A</td>
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<tr>
<td><strong>Maximum DC Input</strong></td>
<td>6,300 W</td>
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<tr>
<td><strong>MPP window</strong></td>
<td>246 – 480 V</td>
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<tr>
<td><strong>Modules per string</strong></td>
<td>6</td>
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<tr>
<td><strong>Parallel strings</strong></td>
<td>18</td>
</tr>
<tr>
<td><strong>Data logger / sensor</strong></td>
<td>Special monitoring system of site owner</td>
</tr>
</tbody>
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**Daytime Yield April 25th, 2010**
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CALYXO MODULES POSSESS THE BEST CARBON FOOT PRINT

Quellen: de Wild-Scholten, Environmental Sustainability of Thin-Film PV, 2009; Fthenakis et.al., Photovoltaics: Life-Cycle analyses; Solar Energy 2010;
THE CdTe TECHNOLOGY SHOWS THE LOWEST CADMIUM EMISSIONS

Life cycle emissions

- Energy use for raw material extraction results in the Life-Cycle-Emissions of Cadmium in PV technology
- Silicon refining is an energy intensive process for production of modules
- Deposition of CdTe on glass is less energy intensive than Si refining

→ The Si module manufacturing process causes higher Cadmium emissions compared to the CdTe technology

Calyxo GmbH is a member of the European PV-Cycle group and takes full responsibility for the lifecycle of its product – keeping the next generation in mind.

That’s why we make provisions for every module to recollect and recycle in 25 years from today.
**SILICON VALLEY TOXIC COALITION SCORED CALYXO WITH 90 POINTS**

<table>
<thead>
<tr>
<th>Company</th>
<th>Points</th>
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<tbody>
<tr>
<td>Abound Solar</td>
<td>63</td>
</tr>
<tr>
<td>Best Solar</td>
<td>0</td>
</tr>
<tr>
<td>Calyxo</td>
<td>90</td>
</tr>
<tr>
<td>Canadian Solar</td>
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<td>DayStar Technology</td>
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<td>Global Solar</td>
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<td>Yingli</td>
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**The Standards**

I. Extended Producer Responsibility and Takeback

II. Supply Chain Monitoring and Green Jobs

III. Chemical Use and Life-Cycle-Analysis

IV. Disclosure of information
IN SUMMARY

• Calyxo has successfully established the atmospheric pressure manufacturing process of CdTe PV modules in a series production

• At present state the modules possess a power level between 55 and 65 W with further potential for power increase to 70 W within one year

• The product shows a very good performance at elevated temperatures and low irradiance

• Company and product are certified according to European industry standards

• Standard inverter and mounting system technology can be used with Calyxo modules

• Using CdTe results in a favorable carbon footprint and extremely low Cd emissions
MEET CALYXO @ INTERSOLAR 2010 ON
BOOTH B6.430

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THANK YOU.