SCHOTT Solar CSP is a subsidiary of SCHOTT Solar AG which is incorporated in the SCHOTT AG

- SCHOTT AG is a B2B technology company founded in Jena, Germany in 1884
- Ranks as number one in the world with many of its products, which include components and systems made from specialty glasses and materials
- €1.84bn sales in 2012/13
- c. 15,400 employees worldwide
SCHOTT Solar CSP develops and supplies receivers for linear focusing CSP technologies
The heart comes from SCHOTT – Receivers as the core components of parabolic trough power plants

- As the core component of the solar field, the quality of the receiver has a decisive influence on how efficiently solar radiation can be converted into heat

- The **Receivers** …
  
  … have to achieve maximum solar absorptance and at the same time minimal emittance of heat
  
  … need to deal with mechanical and thermal stress
  
  … need to show long-term performance stability and keep maintenance costs low during operation
The value chain of CSP parabolic trough power plants is diversified. SCHOTT Solar CSP supplies a key component. Customers include big EPCs, developers, etc.
Headquartered in Mainz, SCHOTT Solar CSP has two production sites: Mitterteich (Germany) and Seville (Spain), as well as dedicated sales forces in the relevant markets.
Outperforming technology, excellent production and service and a unique track record make SCHOTT Solar CSP the most bankable receiver supplier.

**Track record**
- 3.2 GW installed base (out of 4.2 GW total)
- More than 50 projects supplied around the globe
- More than 1 Million receivers delivered

**Excellence in Production and Service**
- Lean manufacturing
- Reliable high volume capability
- Technical customer service on-site
- After-sales service

**Technology**
- Superior product durability and lifetime
- Benchmark product performance
- Strong product development capabilities

---

Most bankable receiver supplier

© SCHOTT Solar CSP GmbH
Track Record: SCHOTT Solar is the unrivaled market leader with over 1 Mio. receivers supplied to more than 50 projects.

CSP capacity installed or under construction

- **2005**: ~0.35 GW
- **2014**: ~3.2 GW

More than 3 GW equipped with SCHOTT PTR®70 receivers.

Over 1.000.000 receivers supplied to more than 50 projects.
## SCHOTT CSP Track record in CSP

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCHOTT</strong> Glass-tube supplier for receiver manufacturers</td>
<td><strong>SCHOTT solar</strong> Receivers for more than 50 parabolic trough power plants</td>
</tr>
<tr>
<td><strong>USA:</strong></td>
<td><strong>USA:</strong></td>
</tr>
<tr>
<td>- 9 commercial-scale parabolic trough power plants “SEGS I – IX” in Californian Mojave Desert</td>
<td>- US Loan Guarantee program</td>
</tr>
<tr>
<td></td>
<td><img src="image1" alt="Nevada Solar One" /> <img src="image2" alt="Mohave Solar" /> <img src="image3" alt="Solana" /></td>
</tr>
<tr>
<td><strong>Spain: Renewable Energy Plan (REP)</strong></td>
<td><strong>Spain: Renewable Energy Plan (REP)</strong></td>
</tr>
<tr>
<td></td>
<td><img src="image4" alt="Andasol 1-3" /> <img src="image5" alt="Solnova 1,3,4" /> <img src="image6" alt="Heloenergy" /></td>
</tr>
<tr>
<td><strong>MENA: Several Gas-Solar hybrid solar plants (ISCCS)</strong></td>
<td><strong>MENA: Several Gas-Solar hybrid solar plants (ISCCS)</strong></td>
</tr>
<tr>
<td></td>
<td><img src="image7" alt="Morocco" /> <img src="image8" alt="Algeria" /> <img src="image9" alt="Egypt" /></td>
</tr>
</tbody>
</table>

- ✔️ plants supplied with SCHOTT PTR®70
- ◯ other suppliers
- ◯ other technologies
Excellence in production: A lean and flexible production setup provides high volume capability

- Lean philosophy as basis for the setup and operation of the receiver manufacturing sites and the supply chain
- Holistic manufacturing approach integrating lean production, quality system and occupational safety
- Continuous improvement / Kaizen

Key Benefits:
- High volume capability
- Stringent cost roadmap
- High production flexibility
- 100% delivery reliability
- High personnel and machine productivity
- Occupational safety
Excellence in Service: SCHOTT’s Technical Customer Service provides on-site support and training

**Key benefits of the Technical Customer Service**

- By providing our expertise and trainings, we **help the customers to improve their performance** and to **reduce their project risks** during plant construction.

- We **avoid “unnecessary” issues** by conducting preventive measures together with the customer, thus increasing the customer satisfaction.

- The customers consider the Technical Customer Service a **USP of SCHOTT**.

**Technical Customer Service on-site presence during CSP project construction phase**

<table>
<thead>
<tr>
<th>Agreement on supply of receivers</th>
<th>Handling &amp; storage</th>
<th>Welding</th>
<th>Transport &amp; mounting</th>
<th>Pressure test etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kick-off meeting</td>
<td>Unloading storage</td>
<td>Unloading of racks, pre-processing, welding, transportation of triples</td>
<td>Transport, mounting</td>
<td>Pressure test, filling with oil, shields</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Quality claims/ lessons learned</td>
</tr>
</tbody>
</table>

= Trainings and/or visits on site
Technology: The receiver is designed for maximum efficiency of the solar field

- The quality of the receiver has a decisive influence on the efficiency of the solar field and the profitability of the CSP power plant.
- The most important issues are:

  - Stability of Glass-to-Metal Seal
  - Solar irradiation
  - Reflection losses glass
  - Reflection losses absorber
  - Shading losses
  - Gas conduction heat losses
  - Vacuum stability
  - Radiation heat losses
SCHOTT PTR®70 Receiver – More than 1 Million already delivered to power plants around the globe

- **Anti-reflective coating of the glass tube**
  ensures high transmittance and high abrasion resistance

- **Absorber coating**
  achieves low emittance and high absorptance of the absorber tube

- **Vacuum insulation**
  minimizes heat conduction losses

- **Durable glass-to-metal seal**
  material combination with matching coefficients of thermal expansion

- **Optimized design of bellows**
  achieves a maximum optical aperture length of the receivers
SCHOTT Solar paves the way to competitiveness of CSP technology

- + 2.9% plant efficiency
- + 1.0% plant efficiency
- + life time extender + improved robustness
- high temperature (550°C)

1st Gen 2nd Gen 3rd Gen 4th Gen SCHOTT PTR® 4th Gen SCHOTT PTR® Advance
400°C 550°C
Based on a new receiver platform, SCHOTT issues three 4\textsuperscript{th} generation receiver products

\textbf{SCHOTT PTR\textsuperscript{®}70 Advance}

The technology leap towards Molten Salts

\textbf{SCHOTT PTR\textsuperscript{®}70 Premium}

The profitability booster

\textbf{SCHOTT PTR\textsuperscript{®}70}

The receiver benchmark in CSP industry
Based on a new receiver platform, SCHOTT issues three 4th generation receiver products:

- **SCHOTT PTR®70 Advance**
  - New steel grade for 550°C
  - Novel absorber coating

- **SCHOTT PTR®70 Premium**
  - Integrated Noble Gas Capsule as lifetime extender

- **SCHOTT PTR®70**
  - New bellow design, suitable for high-temperature operation
  - Glass-to-metal seal with matching coefficients of thermal expansions
  - Protection cap for improved product robustness and easy handling
SCHOTT PTR®70 Premium: Over 40 years of operation, the SCHOTT Premium Receivers facilitate 9% higher electricity output of a CSP plant

**Noble Gas Capsule concept**

- SCHOTT PTR®70 Premium Receiver equipped with noble gas capsule
- A new conceptual design patented by SCHOTT
- Avoids replacement of “hot tubes”
- Can be activated by operator at any time

**Net annual electricity output (MWh) ***

- + 9% total yield
- additional output from activated Noble Gas Receivers
- no action

* case study: location Caceres/Spain, 50 MW with 6hrs thermal storage
SCHOTT PTR®70 Advance: 4 major challenges are addressed for making receiver tubes ready for usage at temperatures up to 550°C

- **Stable performance:**
  - Absorber coating with long lifetime and stable optical and thermal performance

- **Low heat loss:**
  - Absorber coating option with optimized optical parameters at hot end of the loop
  - Bellow specifically designed for low heat loss

- **Steel tubes and bellows:**
  - Steel grade qualified for high temperatures

- **Robust receiver ends:**
  - Glass-to-metal seal material combination accounting for elevated thermal stress
  - Bellows design accounting for higher thermal expansion of absorber tube
SCHOTT Solar CSP received most significant industry awards

CSP Today Award 2012
“Best CSP Technology and Supplier”

CSP Today Award 2011
“Best CSP Technology and Supplier”

CSP Today Award 2010

Germany's Federal President's Prize for Innovation and Technology 2008
Nomination of Dr. Nikolaus Benz and Dr. Thomas Kuckelkorn (Head of R&D SCHOTT Solar CSP)

Bayerischer Energiepreis 2004
SCHOTT Solar CSP is in the inner circle of the international CSP industry

- The DESERTEC concept forms the basis of the “Dii”, an industrial initiative, which aims at accelerated implementation of the DESERTEC Concept.
- Dii was founded on 30th of October 2009 by twelve international companies and the DESERTEC Foundation, with SCHOTT Solar as a founding member.

- Founded in 2007 by ACS, ProtermoSolar and SCHOTT.
- Largest industry association with more than 60 members.
- SCHOTT Solar assumes vice-presidency since the beginning.

- Founded in 2004.
- 100 commercial members, including Abengoa, Acciona, E.ON, Ferrostaal.
- SCHOTT Solar member of the board since 2005.

- German Association for Concentrated Solar Power.
- SCHOTT Solar CSP as a founding member since June 2012.
SCHOTT Solar CSP Key Highlights

1. CSP with high growth potential in sunbelt region of the world, such as MENA, Asia-Pacific, Southern USA and Southern Europe

2. CSP indispensable as balancing power within renewable energy mix because of dispatchability

3. Parabolic trough the only proven CSP technology with industrial scale

4. SCHOTT as leading receiver supplier driven by exceptional customer base and global market access

5. Technological leadership based upon unique know-how of SCHOTT Group (glass-to-metal-seal technology, glass tubes, etc.) as well as strong innovation pipeline of dedicated CSP R&D team

6. Technological leadership protected by strong patent portfolio covering all major aspects of current and future product portfolio