Receiver für Salzschmelzen
Der nächste Schritt in der Parabolrinnentechnologie

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Dr. Thomas Kuckelkorn, Dr. Patrick Haibach, Dr. Hanno Kamp, Dr. Markus Arntzen, Schott Solar CSP GmbH

SCHOTT Solar CSP is the #1 supplier of receivers for parabolic trough solar fields

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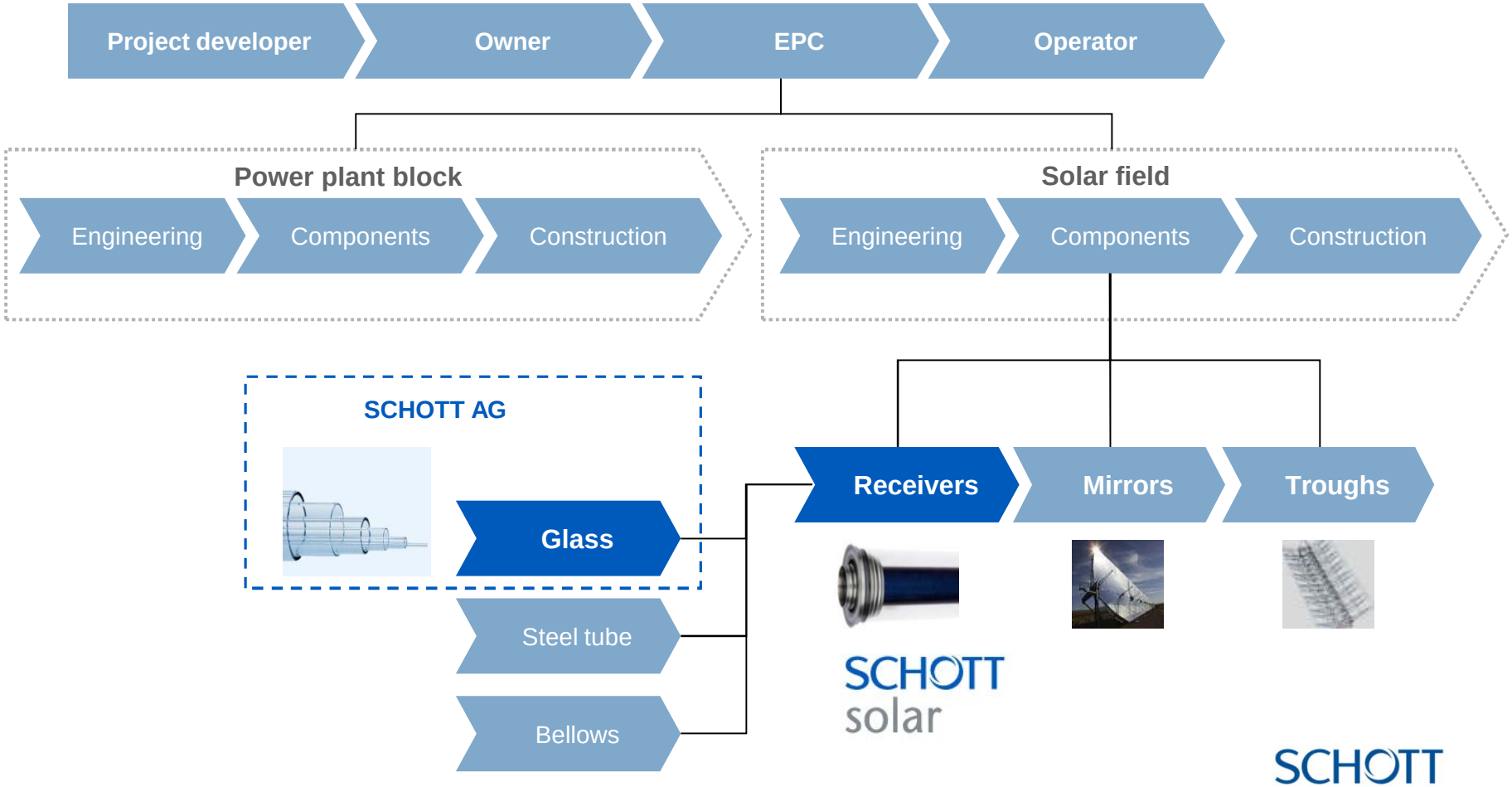
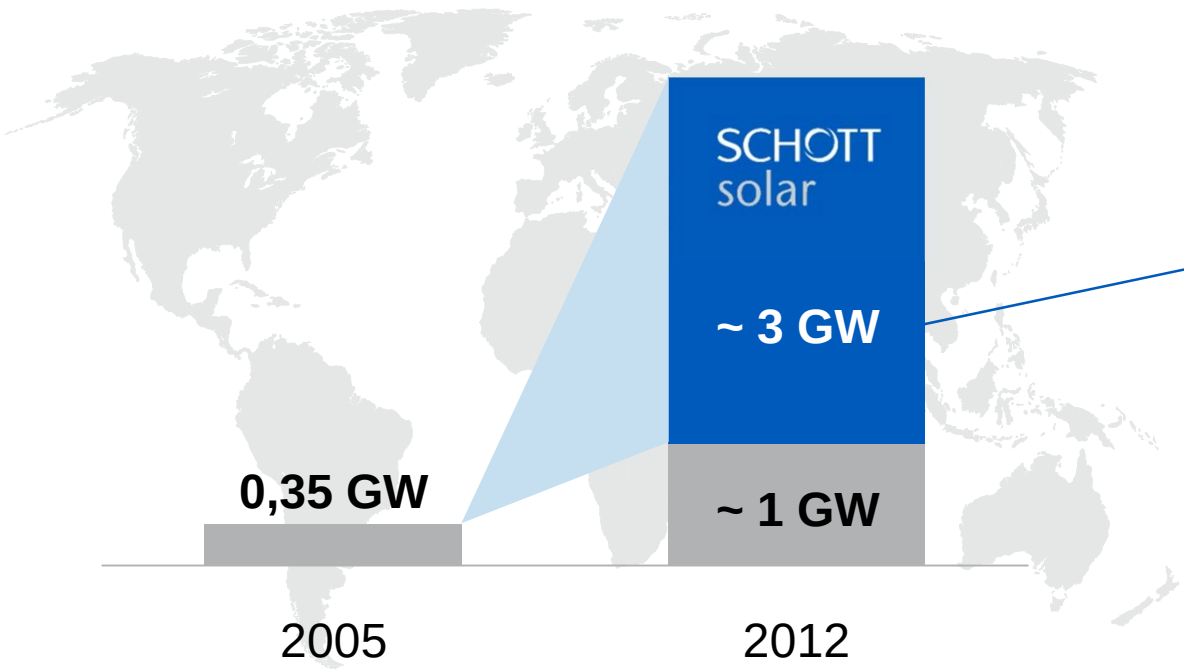
Within the value chain of CSP parabolic trough power plants SCHOTT Solar CSP supplies a key component



Since the market entry in 2005, SCHOTT Solar CSP has achieved a leading market position

CSP capacity installed or under construction



More than 3 Gigawatts capacity equipped with SCHOTT PTR®70 receivers

More than 1 Million receivers supplied to over 50 CSP projects around the globe

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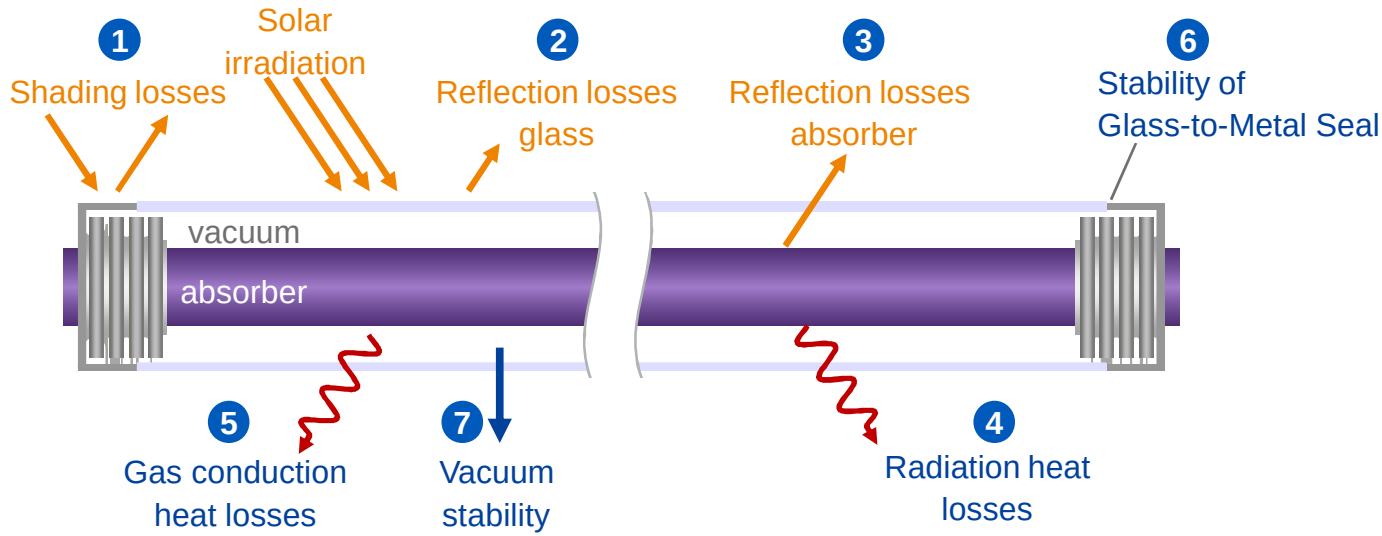
The receiver is a key component in a CSP plant. It is designed for highest efficiency and maximum lifetime



SCHOTT Solar CSP solutions

1 Optimized design of receiver ends
achieves a maximum optical aperture length of the receivers

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

3 4 Absorber coating
achieves low emittance and high absorptance of the absorber tube

5 Vacuum insulation
minimizes heat conduction losses

6 Unique glass-to-metal seal technology
ensures high product reliability for more than 25 years lifetime

7 Noble Gas Capsule
expands receiver lifetime to more than 40 years

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The global CSP industry will achieve significant cost reductions until 2020

LCOE roadmap (€ct per kWh)

- All relevant technology and market studies expect that CSP will show significant cost reductions in the coming years
- Market pressure (e.g. from PV) requires a cost target of 10-12 €ct per kWh in 2020

Sources: assessment by Dii (2012); DLR, *Annual performance simulation and cost estimation for solar power plants in Algeria* (November 2012) – 280MW /13h storage; ESTELA technology roadmap (2012)

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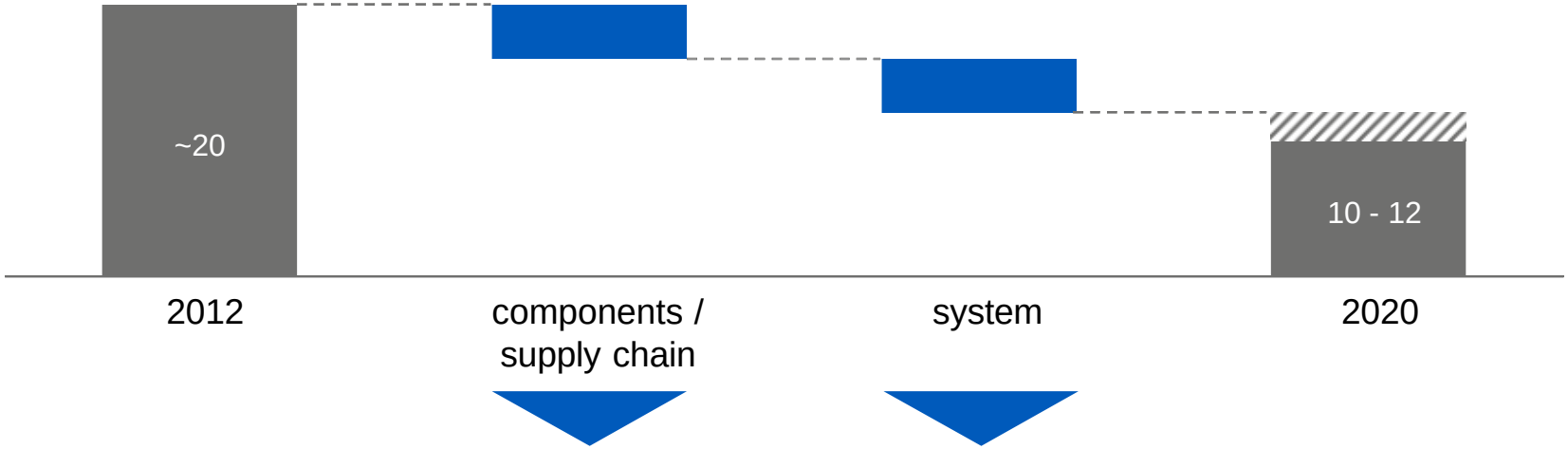
The cost reductions until 2020 will be enabled by technology advancements on component level and system level

LCOE roadmap (€ct per kWh)

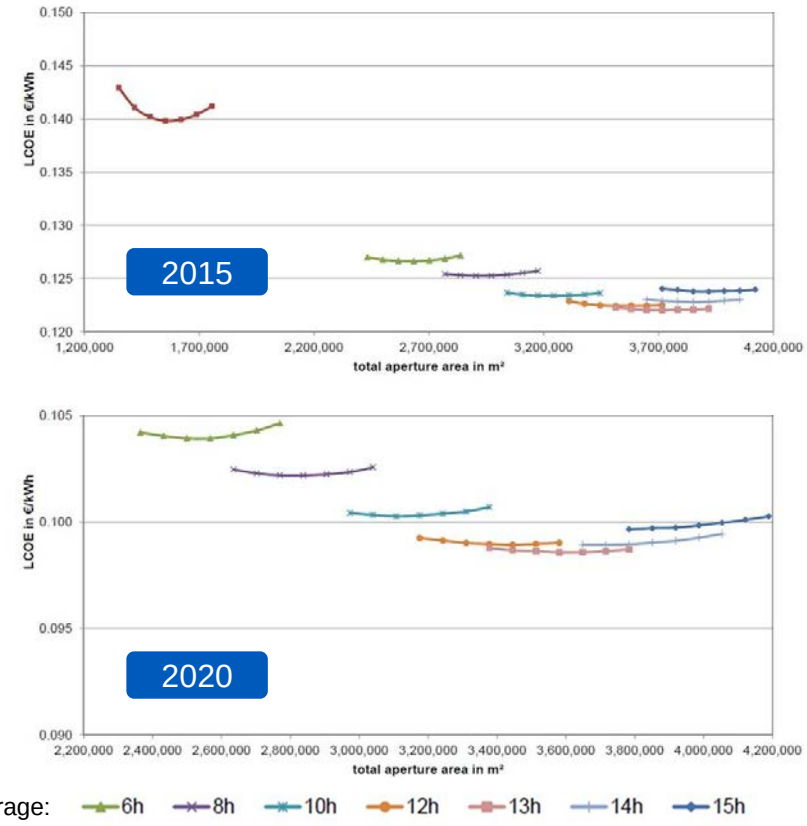


- Facilitating higher operating temperatures on system level
- Higher component efficiencies
- Component scale-up
- Scale effects
- Longer component lifetime

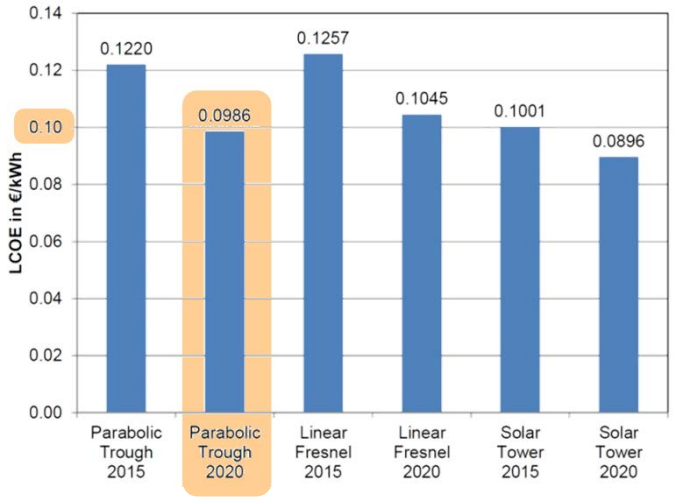
- Higher system efficiency
  - Higher temperatures = Molten Salt as HTF
  - Improved energy conversion
- Sub-system synergies (e.g. solar field, storage)
- Scale-effects
  - Large power plants
  - Optimized supply chain

CSP plants with Molten Salt as HTF will reach LCOE of below 10 €ct/kWh in 2020

LCOE for different solar field and storage sizes of 280 MW Molten Salt parabolic trough plants (€/kWh)



LCOE comparison of 280 MW CSP systems with Molten Salt as HTF (€/kWh)



source: DLR, *Annual performance simulation and cost estimation for solar power plants in Algeria* (November 2012)

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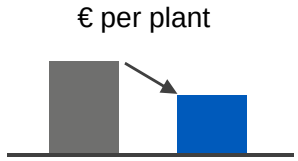
The SCHOTT Innovation Roadmap facilitates improvement of CSP system economics

SCHOTT Solar R&D Pipeline

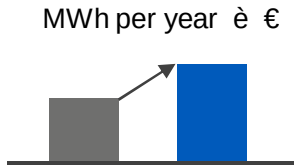
- Receivers for elevated temperatures and alternative heat transfer fluids such as **Molten Salt**
- **Larger receivers** (scale-up) with lower area specific production costs
- Evacuated receiver components for **Fresnel** Technology
- **Receiver shields** and **optimized bellow design** enabling an improved optical efficiency of the receivers
- **Improved coating technology** with better optical properties and suitable for higher temperatures
- **Noble gas capsule as lifetime extender** to ensure maximum profitability of power plant

Effect on CSP system economics

1 **Reduced plant CapEx**



2 **Higher energy yield**



3 **Extended Lifetime**

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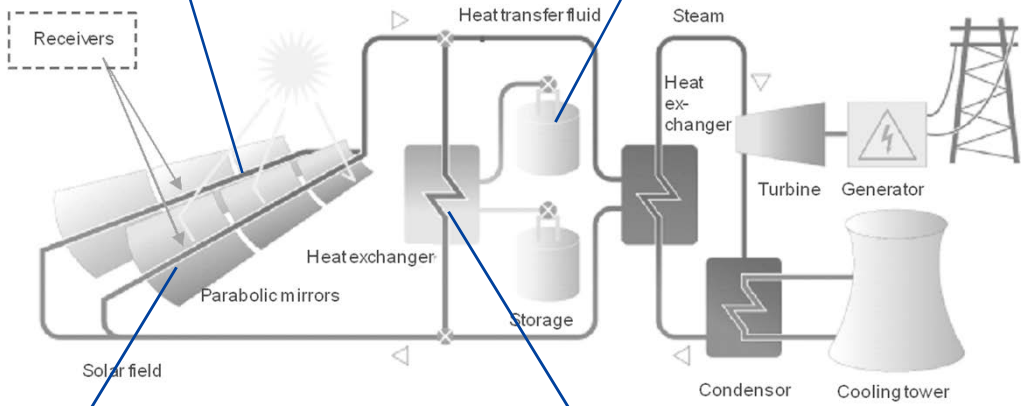
1 Reduced plant CapEx: synergies on plant level

Enhanced plant control

- Freeze protection for Molten Salt
- Heat tracing integration onto receiver

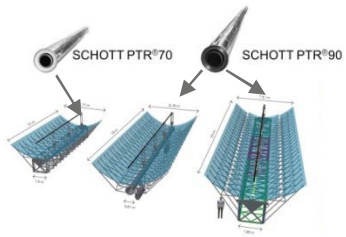
Lower storage capex due to high temp

- Molten Salt receiver
- High-temp coatings (550°C)
- High-temp resistant glass-to-metal seal



Lower Solar field Capex by scale-effects

- Scale-up receivers (PTR®80, PTR®90) for large trough designs
  - Heliotrough
  - Ultimate trough
  - Senertrough
  - …



Omit heat exchangers using Molten Salt as HTF

- Molten Salt receiver
- Molten salt compatible receiver steel

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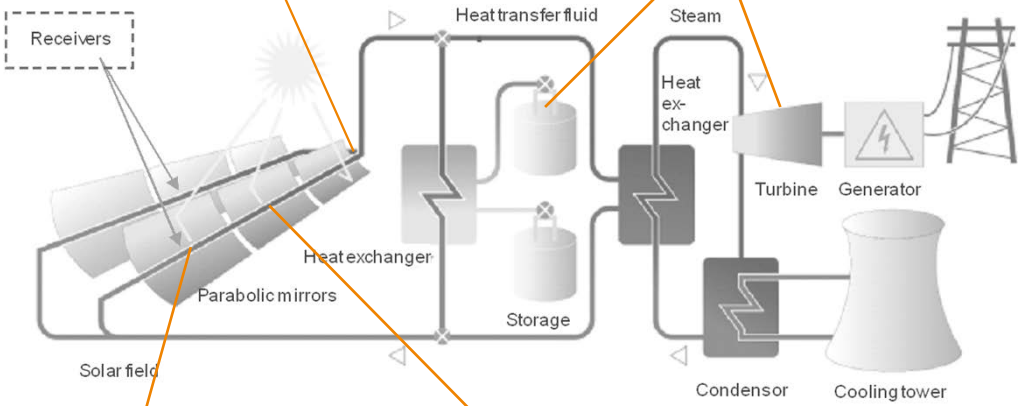
2 Higher energy yield: boost efficiency and profitability

Minimized heat losses

- Optimized SCHOTT Solar CSP receiver clamps
- Receiver-integrated radiation shields

Higher efficiency of storage and power block by higher operating temperature

- Molten Salt receiver
- High-temp coatings (550°C)
- High-temp resistant glass-to-metal seal



Increased light conversion

- SCHOTT Shields with optimized geometry and materials

Increased electricity output over plant lifetime

- Superior absorber coating with benchmark performance from day 1 to receiver lifetime > 25 years

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SCHOTT modifies the proven PTR®70 receiver to fit to Molten Salt Conditions

SCHOTT innovations for Molten Salt receivers

¡ **Define steel grade for 550°C**
today's standard steel grades used in parabolic trough applications are limited to 400°C

¡ **Novel absorber coating**
suitable for operation up to 550°C, low degradation rate
Qualified by accelerated ageing-tests

¡ **New Design of bellows**
to account for higher thermal expansion of the absorber tube and optimized to reduce heat losses and protect the glass to metal sealing

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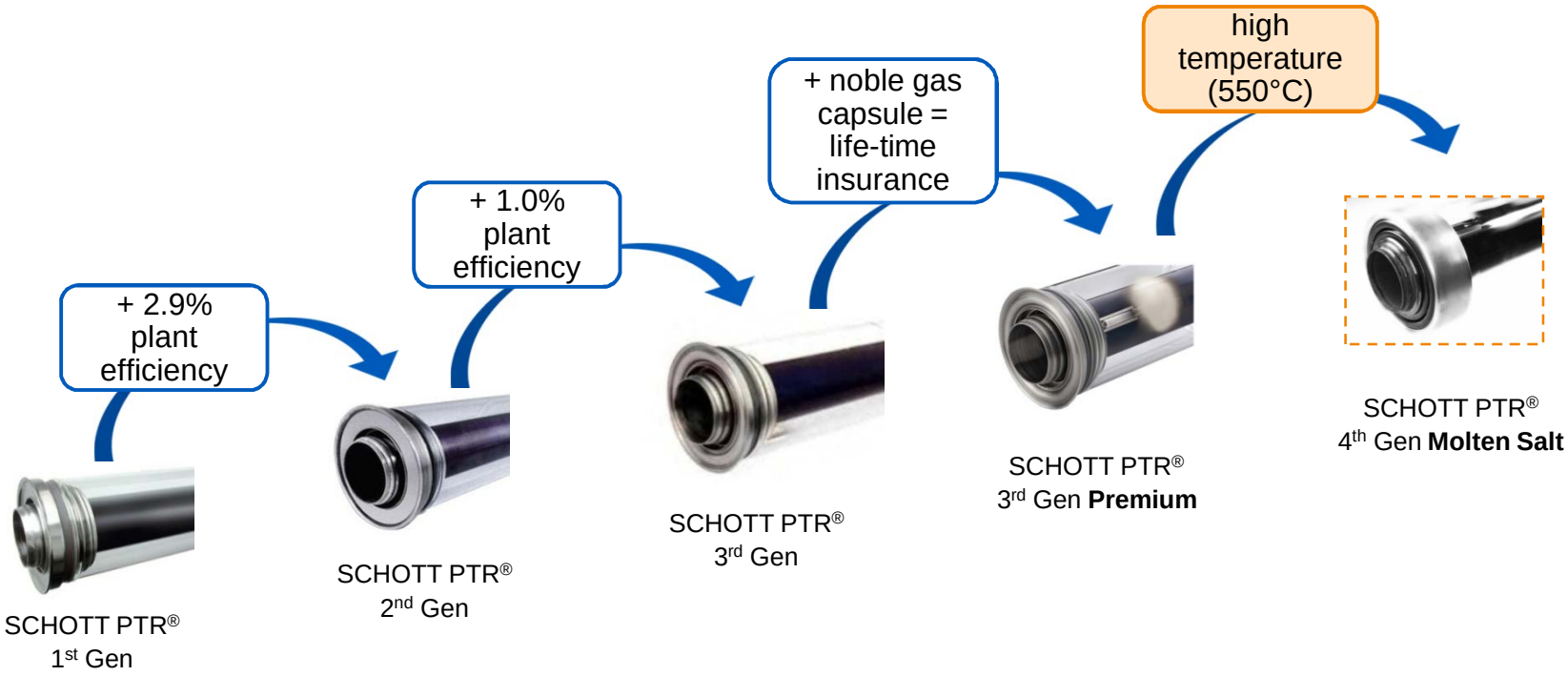
SCHOTT Solar CSP continuously improves the receiver performance. The next generation will facilitate operation temperatures up to 550°C with Molten Salt as heat transfer fluid

SCHOTT PTR®70 Receiver Development



Molten Salt Technology implies design changes, material changes and auxiliary technology for receiver components

Challenges for Molten Salt	Technical Approach	Validation Tasks
¡ Risks of freezing heat transfer fluid in solar field	¡ Heat tracing concept ¡ Design and procedure instruction for receiver heating	¡ Validation of heat tracing concept in commercial solar field ¡ Identify critical operation conditions
¡ Higher thermal stress ¡ Higher corrosion risk for steel parts	¡ Improve durability of receiver component ¡ Design of components ¡ Design of material	¡ Validation and qualification of materials, components and concepts ¡ Simulation ¡ Lab tests for durability ¡ Qualification in test bench and field tests
¡ Higher thermal losses ¡ Higher degradation of coating over lifetime	¡ Coating Design ¡ Improve optical efficiency over lifetime, reduce degradation	¡ Ageing tests of new coating in lab

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Selective absorber for high temperatures: Molten Salt as HTF for higher working temperatures

Molten Salt vs. Therminol

- Pro:
  - Stable up to 500 - 550 °C, non-flammable, non-volatile
  - solidifies quickly in case of leakage, easily disposed
  - No hydrogen release
- Con:
  - High melting temperature (120 - 240 °C)
  - Slightly higher viscosity

Possible Salt mixtures

Salt	Composition	Melting point	Degradation point
Solar Salt	$NaNO_3$ KNO_3	240 °C	> 550 °C
Hitec	$NaNO_3$ KNO_3 $NaNO_2$	140 °C	500 °C
Hitec XL	$NaNO_3$ KNO_3 $Ca(NO_3)_2$	120 °C	500 °C

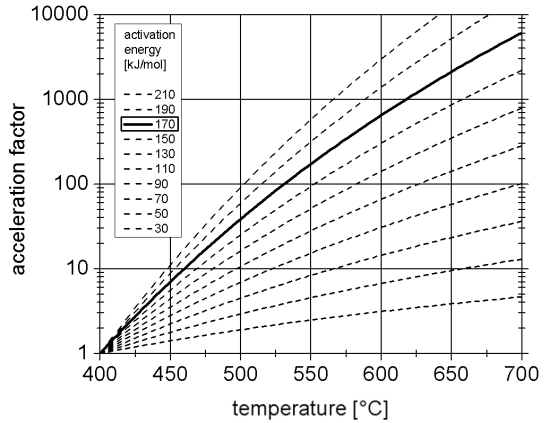
Accelerated ageing tests

Minimum ageing testing time 400°C

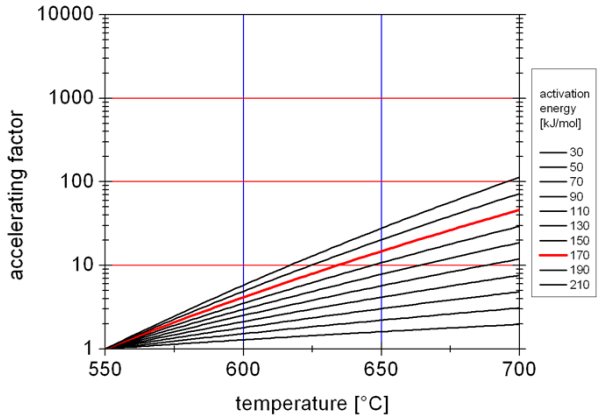
Minimum ageing time [h]	Ageing temperature [°C]
1050	510
643	525
295	550
93	590
16	660
6	700
2	750

Acceleration factors

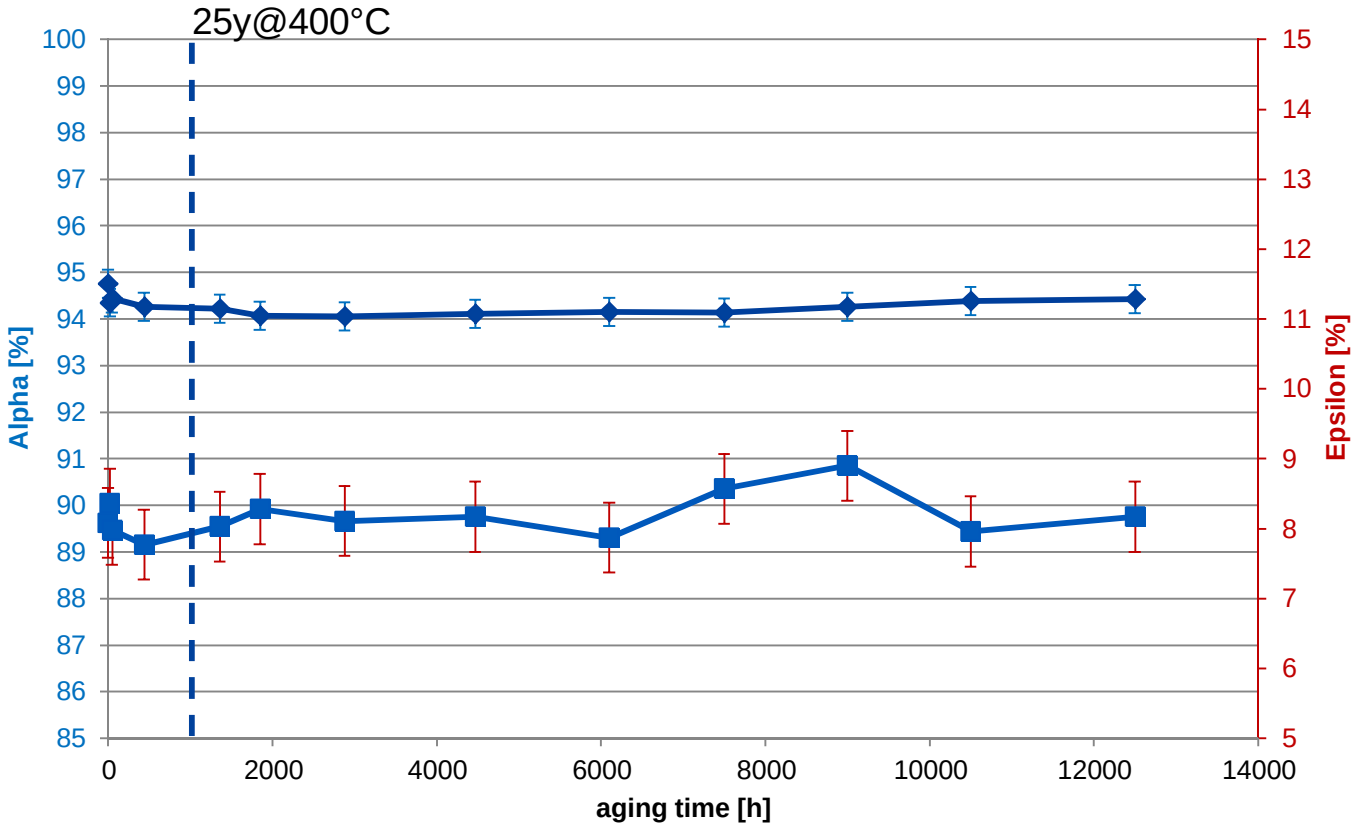
¡ 400 °C



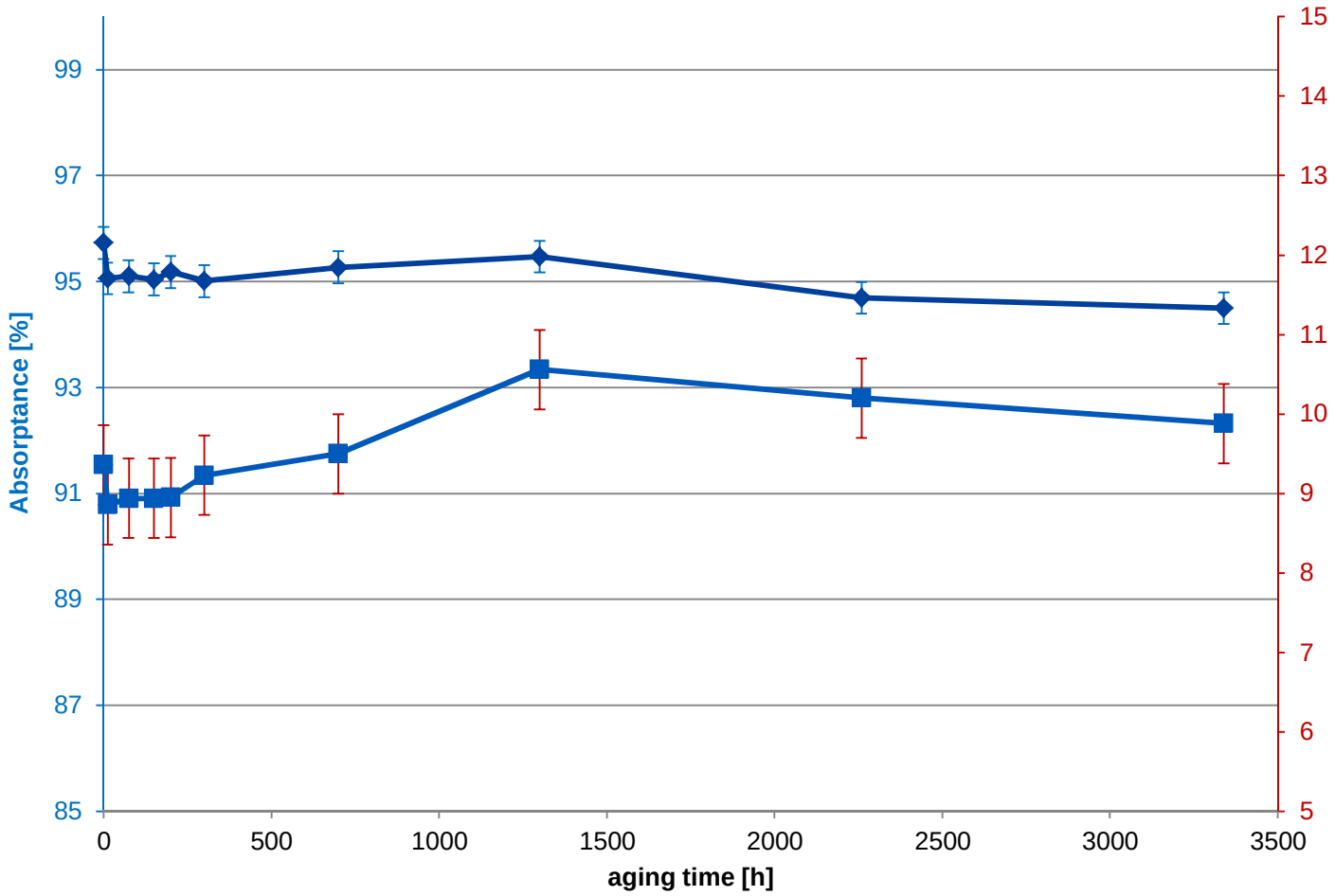
¡ 550 °C



Ageing test at elevated temperature: 510°C



Ageing test at elevated temperature: 590 °C



The first large-scale demonstration of a Molten Salt parabolic trough CSP plant is being realized in Europe. SCHOTT Solar CSP is engaged in the respective EU funded R&D

FP7 project: ARCHETYPE SW 550

- Location: Passo Martino (CT) – Sicily, Italy
- Technology: CSP solar plant integrated with a biomass furnace and with a reverse osmosis plant
- Capacity: **30 MWe (gross),** 132 MW thermal (76 MW salt to steam generator; 44 biomass furnace; gas fired aux boilers 12 MW)
- Net electricity production: 125 GWh/y as result of **85 GWh/y (solar)** + 40 GWh/y (biomass)

SCHOTT Solar CSP project scope (R&D)

- Qualification of receiver and all receiver components for operation with molten salt at 550°C operating temperature
- Choice of materials
  - Stable and durable steel for the absorber tube (cooperation with steel manufacturer)
  - Steel compatibility to molten nitrate mixtures
- Optimized two-product strategy for the temperature range 300°C to 550°C
- System technology
  - Clamps, shields
  - Heat tracing / anti freezing
- Demonstration

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Summary

- The global CSP industry will achieve significant cost reductions until 2020. The cost reductions until 2020 will be enabled by component improvements and system integration
- Key levers on system level for cost reductions are:
  - Higher system efficiency by higher operating temperatures
  - Sub-system synergies (e.g. solar field, storage)
  - Scale-effects
- SCHOTT Solar CSP currently develops the 4th receiver generation facilitating the technology leap towards operation temperatures up to 550°C with Molten Salt as heat transfer fluid
- The first large-scale demonstration of a Molten Salt parabolic trough CSP plant is being realized within Europe. SCHOTT is strongly in the respective key R&D topics

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