Solar power night and day
Dispatchable power made available by industrial steam turbines
Unlock the full potential of solar power

Solar energy is free, abundant and inexhaustible. In the face of global warming, with energy policies calling for wide-scale use of renewable and sustainable technologies, solar power projects are proving increasingly valuable in the reduction of fossil energy.

The profitability of a concentrated solar thermal power plant (CSP) heavily depends on the efficiency of the power generation equipment, namely the steam turbine generator set. As market leader and the number one company when it comes to installed capacity, Siemens is your partner of choice for CSP steam turbine solutions.

Make full use of the CSP advantages

- **Being independent**
  CSP offers the opportunity to supplement fossil power generation or even abandon fossil fuels completely in those areas located in the sunbelt. CSP operators can become independent from logistical issues involving fossil fuels and the fluctuation of fossil fuel prices.

- **Being green**
  CSP is an environmentally sound and sustainable technology. It provides power that is generated without carbon dioxide, with low emissions for air and water, and a low noise level. This is why many governments subsidize this technology.

- **Reliably meeting the demand**
  Overall, CSP peak energy production coincides with peak demand. But even when the sun sets or is blocked by clouds its energy is still available: The energy can be used immediately or – if coupled with molten salt and thermal energy storage systems – can be stored for later use to drive a heat engine and match utility peak power demands.

- **24 hours power supply**
  Moreover, CSP can easily be integrated with other technologies such as heat storage or photovoltaic systems. This characteristic makes CSP, unlike stand-alone photovoltaic or wind power, a reliable power generation solution that allows delivery on demand and at any time. So-called integrated Solar Combined-Cycle (ISCC) systems for supplementary firing provide a potentially smooth migration path from fossil to solar power.
Typical regimes of operation

The number of concentrated solar power plants has increased tremendously in the past ten years. Today we see many different regimes of operation, each of which poses a different challenge to power generation equipment. The design of each steam turbine is adapted to these challenges.

Examples for the regimes of operation for a solarthermal power plant, with a power output of 50 MW:

- **Challenge:** fast startups for optimal use of sunlight hours, daily starts necessary
  - **Benefit:** extended time for power generation
  - **Benefit:** baseload power generation
  - **Challenge:** huge heat storage

- **Parabolic trough operation during sunlight hours only**
- **Parabolic trough with heat storage**
- **Parabolic trough with 24/7 heat storage baseload operation**

- **Challenge:** huge heat storage

- **Benefit:** efficient fuel management
  - **Benefit:** baseload operation
  - **Benefit:** extended operation with 2 daily CSP-starts

- **Hybrid power plant, e.g. with combined cycle or biomass-fueled plant**
- **Hybrid power plant with photovoltaic solution**
- **Hybrid power plant with photovoltaic solution, extended operation with 2 daily CSP-starts**

Siemens delivers highly customized steam turbines that fulfill special technical demands required by CSP technology. Due to their highly flexible operational mode the turbines can be optimally integrated in your daily processes. Our experts not only assist you in finding the right equipment. We also have a deep understanding of thermodynamics and CSP processes, which is the key to tailor-made solutions and a successful concentrated solar power plant.
Covering all aspects of CSP technology, Siemens provides:

- Consulting during the project development process, e.g. optimization of water-steam-cycle
- Financing (Siemens Financial Service)
- Highly efficient reheat turbines and auxiliaries, shortening the payback period of your investment
- Equipment designed for daily start-up and shutdown as well as rapid start-up times
- Daily cycling with low minimum load
- Partial and full load operation
- Shipping of fully assembled turbines for easy installation at site
- Turbines with axial and radial exhaust available for best fit into the overall plant concept
Which technology fits your needs best?

Parabolic trough, solar tower, or integrated solar combined-cycle (ISCC)? There is a broad scope of CSP technologies available. We provide power generation for all of these technologies.

Thanks to our long-term experience we can provide you with an appropriate and individual consulting in the conception phase in order to help you select the technology which fits your requirements best.

With our broad industrial steam turbine portfolio ranging from a power output of < 10 kW to 250 MW, we offer various turbines and auxiliary equipment for CSP. Our experts provide consultancy regarding steam cycle optimization, maintenance, and financial solutions.

Parabolic trough, solar tower, or integrated solar combined-cycle (ISCC)? There is a broad scope of CSP technologies available. We provide power generation for all of these technologies.

Thanks to our long-term experience we can provide you with an appropriate and individual consulting in the conception phase in order to help you select the technology which fits your requirements best.

With our broad industrial steam turbine portfolio ranging from a power output of < 10 kW to 250 MW, we offer various turbines and auxiliary equipment for CSP. Our experts provide consultancy regarding steam cycle optimization, maintenance, and financial solutions.

Parabolic systems use trough-shaped mirrors to focus sunlight onto an absorber tube placed in the trough's focal line to heat the heat transfer fluid. It is circulated in these tubes and pumped through heat exchangers to produce steam.

• Proven reliability
• Usable even with hazy air

Efficiency
14 %–20 %

Steam Condition
380–415 °C/100 bar

A circular array of flat sun tracking mirrors focuses sunlight on to a central receiver at the top of a tower. A heat transfer medium in the receiver absorbs the thermal energy and transfers it into the steam cycle to generate superheated steam for the turbine.

• High plant efficiency from high steam temperatures and pressures
• High flexibility in plant construction

Efficiency
23 %–35 %

Steam Condition
540–565 °C/100–180 bar

Increased performance with reheat systems

Integrating a steam reheat system into your CSP plant is one of the best ways to increase overall plant performance. With the Siemens reheat turbine package live steam is fed through a high pressure (HP) turbine, returned to the steam generator to increase the steam temperature and then passed through a low pressure (LP) turbine. Raising the temperature of the steam passing from a high to a low-pressure turbine allows for greater output using the same amount of fuel. Siemens offers single and double-casing reheat solutions. You can also use our reheat solutions for a power output of 10 to 12 MW or below.

Steam turbines most often used with CSP
Double-casing reheat solutions

SST-800/500

A dual casing reheat solution with SST-800/500 steam turbine has a long tradition at this segment. This highly reliable and proven technology is suitable for the large volumes often featured in parabolic trough applications.

Thanks to the flexible turbine design, the turbo set can be adapted exactly to the local plant operating conditions.

<table>
<thead>
<tr>
<th>SST-800/500</th>
<th>Power output</th>
<th>up to 250 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>3,000 to 3,600 rpm</td>
<td></td>
</tr>
<tr>
<td>Live steam parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet pressure</td>
<td>up to 165 bar / up to 2,393 psi</td>
<td></td>
</tr>
<tr>
<td>Inlet temperature</td>
<td>up to 565 °C / up to 1,050 °F</td>
<td></td>
</tr>
<tr>
<td>Uncontrolled extractions (up to 7)</td>
<td>various pressure levels</td>
<td></td>
</tr>
</tbody>
</table>

SST-700/900

The pre-defined casing configurations (called fixed casings) consist of a high-pressure backpressure turbine and a combined intermediate/low-pressure condensing turbine. This fixed design enables short manufacturing periods and fast ex-works delivery.

To make best use of thermodynamical phenomena and depending on the volume flow, we offer configurations with fast spinning high pressure turbine and gearbox as well as a setup with direct coupling between high pressure turbine and generator.

<table>
<thead>
<tr>
<th>SST-700/900</th>
<th>Power output</th>
<th>up to 250 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>3,000 to 3,600 rpm</td>
<td></td>
</tr>
<tr>
<td>Live steam parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet pressure</td>
<td>up to 180 bar / up to 2,611 psi</td>
<td></td>
</tr>
<tr>
<td>Inlet temperature</td>
<td>up to 565 °C / up to 1,050 °F</td>
<td></td>
</tr>
<tr>
<td>Uncontrolled extractions (up to 7)</td>
<td>various pressure levels</td>
<td></td>
</tr>
</tbody>
</table>

Single casing reheat solutions

Other members of the reheat solution family are the single casing reheat steam turbines, such as the SST-600 and SST-800. The compact design combined with most modern technology allows the inlet and reheat steam temperature up to 430 °C (parabolic trough) or 565°C (solar tower). The state of the art blade and sealing technology make this steam turbine very attractive for power output up to 120 MW. The tailor-made steam turbine design allows controlled extraction of the steam, which is fed back into the cycle for reheat purposes and then readmitted to the steam turbine.
The best of references
Some of our success stories

> 4.7 GW electricity from solar power

In the past 20 years, over 70 Siemens turbosets installed in solarthermal power plant sum up to more than 4.7 GW electricity supply.

1. Ouarzazate (Morocco)
2. Boulder City (USA)
3. Granada (Spain)
4. Ivanpah (USA)
5. Kuraymat (Egypt)
6. Lebrija (Spain)
7. Fuentes de Analucia (Spain)
The best of references

1. **Siemens steam turbines for to date largest solar energy project in the world, Ouarzazate/Morocco**

   Three dual-casing steam turbines put into service at the Noor project site – the most ambitious solar power project in the world. Steam turbines operate in parabolic trough (Noor I, II) and solar tower plant (Noor III).

   - Steam turbines: 2 × SST-700/900, 1 × SST-900/1600
   - Noor I (700/900): 380°C/101 bar
   - Noor II (800/500): 380°C/101 bar
   - Noor III (700/900): 543°C/140 bar

2. **NEVADA SOLAR ONE, Boulder City, Nevada, USA**

   Parabolic trough (Oil) 64 MW(e)

   The 64 MW solar power plant with solar trough technology has been in operation since 2007. It was built by Acciona Solar Power, a partially owned subsidiary of Spanish company Acciona Energy. Nevada Solar One uses 760 parabolic troughs, consisting of more than 180,000 mirrors, to concentrate the sun’s rays onto receivers placed at the focal axis of the troughs. Thermal oil that heats up to 390°C flows through the receiver tubes and is used to produce steam to drive the steam turbine. The plant powers about 40,000 households.

   - Steam turbine: Siemens SST-700
   - Power output: up to 74 MW(e)
   - Inlet pressure: 90 bar/130 psi
   - Inlet temperature: 371°C/698°F

3. **ANDASOL 1+2, Granada, Spain**

   Parabolic trough (Oil) 50 MW(e) each

   The two CSP plants are located in the Granada area, each covering a field of 1.95 km² of which the mirror field size is about 510,000 m². Both Andasol plants have a thermal storage system using molten salt to absorb part of the heat produced in the solar field during the day. This process almost doubles the number of operational hours per year at the solar thermal power plant. Andasol I went online in 2008, Andasol II one year later.

   - Steam turbine: 2 × Siemens SST-700
   - Power output: 2 × 50 MW(e)
   - Inlet pressure: 100 bar/1,450 psi
   - Inlet temperature: 371°C/698°F

   Andasol 1 in southern Spain was the first parabolic trough plant that went online in Europe

4. **IVANPAH SOLAR POWER COMPLEX, California, USA**

   Solar Power Tower (Water/Direct Steam) 3 plants, 392 MW(e) in total

   BrightSource Energy, a privately owned energy company, brought the Ivanpah Solar Power complex online in 2014. It is located in California’s Mojave Desert. It consists of three separate plants using tower technology and produces approximately 400 MW electricity to the US utilities PG&E and Southern California Edison. The whole complex generates enough electricity to power more than 140,000 homes.

   - Steam turbine: 3 × Siemens SST-900
   - Power output: 123 MW(e)
   - Inlet pressure: 160 bar/2,321 psi
   - Inlet temperature: 550°C/1,004°F

BrightSource Energy, a privately owned energy company, brought the Ivanpah Solar Power complex online in 2014. It is located in California’s Mojave Desert. It consists of three separate plants using tower technology and produces approximately 400 MW electricity to the US utilities PG&E and Southern California Edison. The whole complex generates enough electricity to power more than 140,000 homes.
The best of references

5. **KURAYMAT, Egypt**
   **Integrated Solar Combined Cycle (ISCC) plant 126 MW(e)**
   The 126 MW ISCC plant, located about 90 km south of Cairo on the eastern side of the river Nile, started in autumn 2010. It consists of a parabolic trough solar field capable of generating about 110 MW(th) of solar heat at a temperature of 400°C, one 74 MW(e) gas turbine and one single casing condensing Siemens SST-900 steam turbine with generator. Further enlargement of the solar field in the future is possible, and this would raise the plant capacity to around 150 MW.
   - **Steam turbine:** Siemens SST-900
   - **Power output:** 77 MW(e)
   - **Inlet pressure:** 92 bar / 1,334 psi
   - **Inlet temperature:** 560°C / 1,040°F

6. **LEBRIJA 1, Lebrija, Spain**
   **Parabolic trough (Oil) 49.9 MW(e)**
   Lebrija 1, located in southern Spain in the province of Seville, Andalusia, is a CSP plant predominantly manufactured with Siemens components. The solar field, including nearly 6,000 parabolic collectors, approximately 19,000 solar receivers, and more than 150,000 parabolic reflectors. The power block was built by Valoriza, using a Siemens SST-700 reheat steam turbine. The plant supplies over 50,000 Spanish households with electricity.
   - **Steam turbine:** Siemens SST-700
   - **Power output:** up to 52 MW(e)
   - **Inlet pressure:** 104 bar / 1,523 psi
   - **Inlet temperature:** 377°C / 711°F

7. **GEMASOLAR, Fuentes de Andalucía, Spain**
   **Solar power tower (Molten salt) 17 MW(e)**
   The Gemasolar project, formerly called Solar Tres, was developed by Torresol Energy, a joint venture between Sener and Masdar. Construction of the plant started in late 2008. Situated in the province of Seville, it consists of a 120 m high solar tower and a heliostat field of about 320,000 m². Gemasolar will be the world’s first utility-grade solar power plant with a central tower that uses molten salt for the heat transfer between receiver and heat exchangers. Surplus heat is stored in the hot salt tank of a thermal storage system. Siemens supplied a SST-600 two-cylinder reheat steam turbine in 2009.
   - **Steam turbine:** Siemens SST-600
   - **Power output:** up to 19 MW(e)
   - **Inlet pressure:** 105 bar / 1,523 psi
   - **Inlet temperature:** 542°C / 1,008°F