

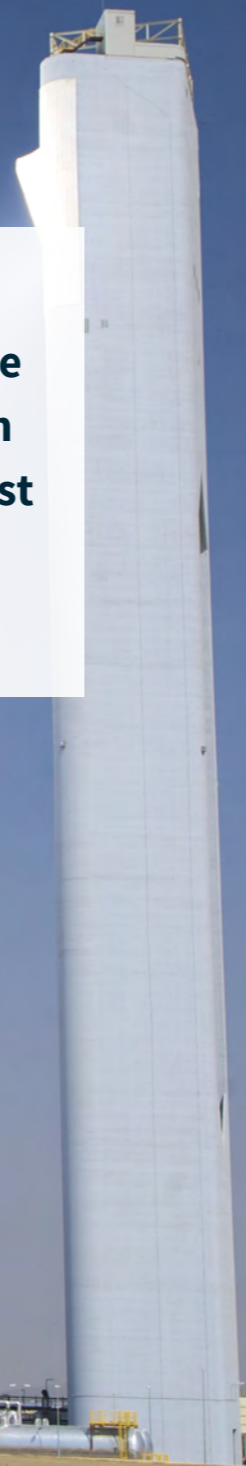


CSP POWER PLANT TECHNOLOGIES

Lowering cost of energy with steam generation systems and solar tower receivers



“
With the vision to change the way we produce energy today, it is a fundamental principle in our engineering design to reduce levelized cost of energy for our customers.
”



Aalborg CSP is leading developer and supplier of concentrated solar power (CSP) systems and technologies.

Our globally recognised solutions for CSP power plants are based on more than 25 years of experience with traditional steam boilers uniquely adapted to the CSP market requirements for high availability and reliability. We design and deliver steam generation systems for CSP plants using molten salt or different types of thermal oil as heat transfer fluids as well as molten salt and steam solar tower receivers.



Aalborg CSP places strong focus on R&D activities and partners with knowledge-based companies and institutions to create leading-edge technologies. As a result, the Aalborg CSP engineering design is centred on a value-adding concept providing solutions that excel in operation, increase plant revenue and contribute to a greener future.

Operational excellence

We utilise best practices and tested concepts to ensure that our technologies deliver on promises and reliably operate with low maintenance requirements. Our performance track records confidently prove that solutions delivered by Aalborg CSP are guaranteed to perform as expected.

Increasing plant revenue

It is a fundamental principle in our engineering design to lower cost of energy for our customers. Even if this means to go beyond standard specifications, our experts aim to suggest solutions that reduce both CAPEX (capital expenditure) and OPEX (operational expenditure) in system design as well as create optimised system performance.

Contributing to a greener future

With a vision to change the way we produce energy today, our aim is to design solutions that will accelerate the world's renewable energy transition. We do that by continuous product development in order to make more competitive green energy solutions.

FEASIBILITY STUDY

- Technical and economical analysis and evaluation of a proposed project

PRE- ENGINEERING

- Plan and estimate for optimized technology development

ENGINEERING DESIGN

- Basic engineering
- Detailed engineering

PROCUREMENT & MANUFACTURING

- Supplier selection to match project requirements
- Technology manufacturing through trusted partners

FINAL DELIVERY

- Optional installation and commissioning
- Training in operation

OPERATION & MAINTENANCE

- Technical inspection
- System upgrades

SGS – STEAM GENERATION SYSTEMS

INCREASING POWER PLANT REVENUE

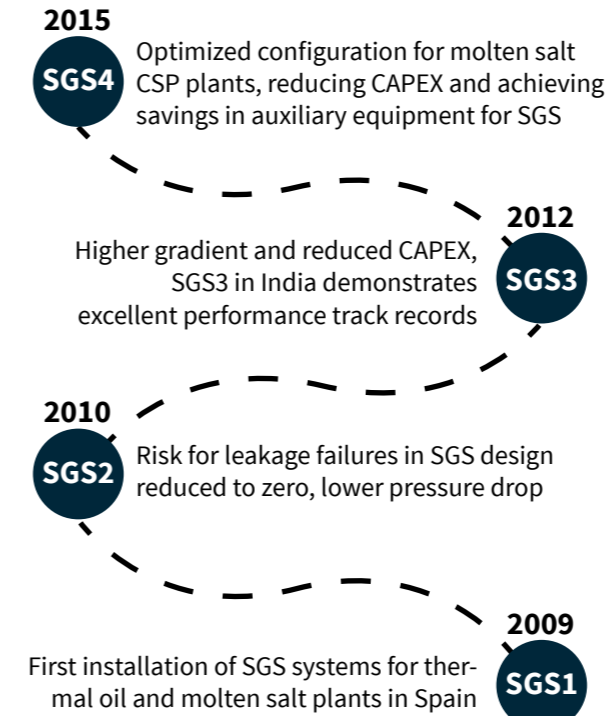
SGS CONFIGURATIONS

FOR THERMAL OIL AND MOLTEN SALT CSP PLANTS

To comply with the CSP power plants' critical requirements for cyclic operational time (frequent starts/stops) and high operational steam pressure (100bar or more), Aalborg CSP developed the SGS steam generator system that has gone through several performance and price optimization practices since its first installation. Today we supply the SGS3 configuration for thermal oil CSP plants and the SGS4 configuration for molten salt CSP plants.

The SGS equipment are designed based on traditional power boiler principles and they are therefore superior to ordinary heat exchangers, providing multiple operational benefits. This design philosophy has proven high reliability and availability in some of the most efficient CSP plants in the world and it was also recognised by leading industry experts:

- CSP Today India Technology and Supplier Award 2013
- Indiasol CSP Technology and Supplier Award 2014
- International CSP Technology Innovation Award 2014



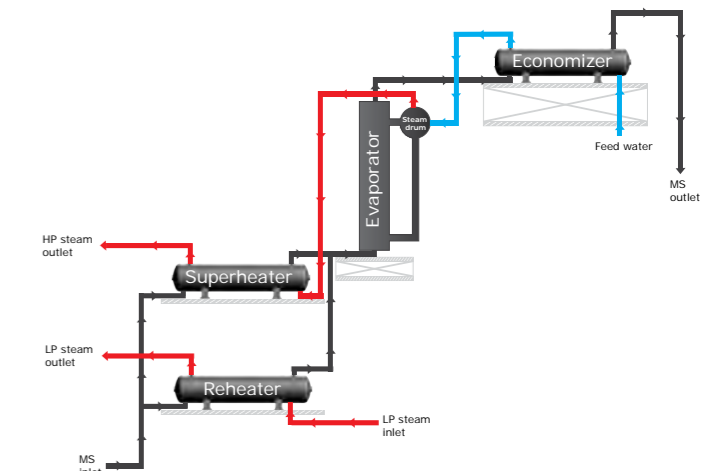
SGS4 configuration for molten salt plants

The optimized SGS4 system is developed as shell-and-tube type with header-and-coil equipment complying with ASME and TEMA standards. The most significant feature of the optimized SGS4 technology is that it allows the shell-and-tube design to have molten salt on the shell side of all components while maintaining the option to use natural circulation for optimal and stable operation. This translates into up to €4 million saving on auxiliary equipment for the steam generation system designed for a 100MWe reference plant as well as lower operation and maintenance costs for two main reasons:

1. No need for circulation pumps
The natural circulation in the evaporator unit eliminates the use of circulation pumps and the initial investment costs associated with it. Furthermore, the electricity consumption and the risk for operational failures are greatly reduced.

2. Reduced amount of venting and drain valves
The elevated layout contributes to automatic venting and achieves easy draining as the molten salt flows by gravity alone. Therefore, there is less need for venting and drain valves, enabling the customers to save on supporting equipment that they would normally have to purchase. The reduced amount of valves also makes operation and maintenance of the plant easier, especially in typical cases, such as molten salt crystallization, when cleaning of multiple valves becomes a costly burden.

Cost-optimal design
The SGS4 configuration allows smaller material thickness owing to an upgrade in the placement of tube bundles and pipes. While the basic component design is the same as the previous editions, decrease in the material thickness reduces the weight of the equipment significantly and lowers CAPEX of the system by 10%.



Key operational benefits

RAPID RAMP-UP

Up to 9°C/min ramp-up time therefore 30 minutes extra energy production during daily start-ups and load changes

LEAKAGE FREE DESIGN

No lost revenue from downtime and less operation & maintenance requirements, backed by a 5-year guarantee

LOW PRESSURE DROP

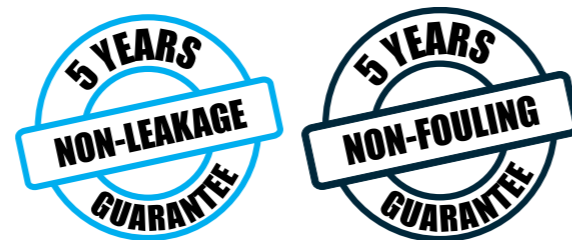
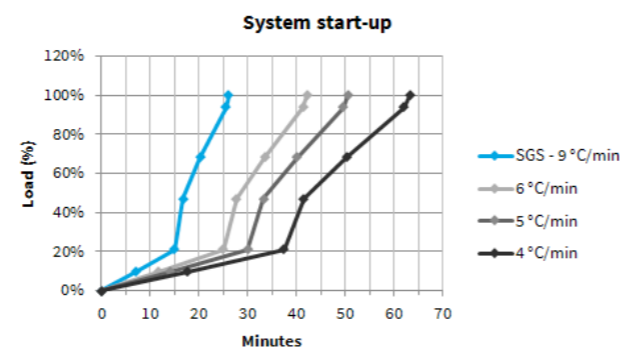
Designed to be around 1-2 bar lowering CAPEX for heat transfer fluid pumps and reducing pump operational costs

LOW MAINTENANCE REQUIREMENTS

Easy to install and operate, fast reaction under all operating conditions

NO FOULING

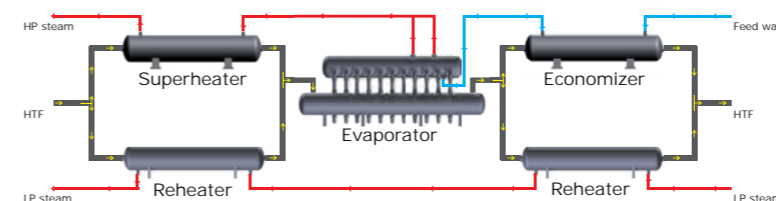
Large diameters and tubes with improved circulation eliminate risk for fouling, backed by a 5-year guarantee



SGS3 configuration for thermal oil plants

The SGS3 system is developed as shell-and-tube type with header-and-coil equipment complying with ASME and TEMA standards.

The SGS3 design consists of five components: evaporator, superheater, two reheaters and economizer. The evaporator is based on natural circulation which ensures very high steam quality and lowers costs as it avoids the use of forced pumping. It also has low material thickness reducing the weight of the equipment significantly. The SGS3 design uses large and widely spaced tubes. Operation is therefore well below the critical heat flux and it is therefore stable and safe.



SOLAR TOWER RECEIVERS

DIRECT STEAM OR MOLTEN SALT

SELECTED PROJECTS

GLOBAL ACTIVITIES

The solar tower receivers developed by Aalborg CSP are all state-of-the-art solutions that have been tested and proven by a variety of demo and fully operational plants. The steam and molten salt systems have demonstrated excellent performance track records since their first installation. All systems are optimized in terms of performance and cost.

The steam systems use natural circulation thereby eliminate the use of forced pumping. The steam is heated directly without any kind of thermal oil. These two technological advantages together create high steam purity, increased system efficiency along with low investment and maintenance costs.

The molten salt systems rely on a special heat tracing system and apply resistant materials in order to minimize risk for operational failures typically associated with molten salt plants. Aalborg CSP has a proven design for molten salt systems and we have conducted many engineering studies for new technology development.



50MWe
steam
generation
system
(thermal oil)

Godawari / India



5x50MWe
steam
generation
system
(thermal oil)

Spain

36MWt
Integrated Energy
System based on CSP
tower technology

Sundrop Farms /
Australia



Direct steam

NATURAL STEAM CIRCULATION

- No forced circulation by pumps in steam systems
- Highest possible heat flux/m²
- Increases the overall effectiveness by up to 10%

DIRECT STEAM GENERATION – NO OIL

- Saturated steam
- Superheated steam with extra set of receiver panels

STEAM DRUM BASED ON ABMA 92 STANDARDS

- Circulation ratio, Required steam space, Sufficient retention time and Sizing of the cyclones and chevrons



Molten salt

FLEXIBLE SOLUTIONS

- The molten salt tower is tailored to individual project requirements

CUSTOMIZED SOLUTION

- Customized alloy-mix able to cope with high temperatures
- Strong supply-chain for tailor-made instrumentations

SPECIAL HEAT TRACING SYSTEM

- Well-developed and tested concept for temperature control



25MWe
steam
generation
system
(thermal oil)

Cargo / India

20MWe
solar
tower
receiver
(direct steam)

Spain

11MWe
solar
tower
receiver
(direct steam)

Spain

4,2MWt
steam
generation
system
(molten salt)

Spain

5MWt
solar
tower
receiver
(direct steam)

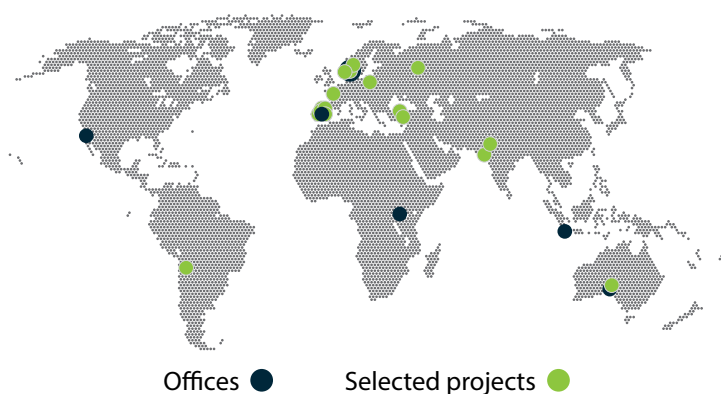
Greenway / Turkey

100MWe
Pre-engineering
study for
solar tower receiver
(molten salt)

South America

AALBORG CSP

- Changing Energy



CHANGING ENERGY

Aalborg CSP is leading developer and supplier of innovative renewable technologies with the definite purpose to change the way we produce energy today. Relying on extensive experience from some of the most efficient concentrated solar power (CSP) projects around the world, the company designs and delivers green technologies and integrated energy systems to lower cost of energy for industries and power plants worldwide.



**VALUE-ADDING
ENGINEERING DESIGN**



**TECHNOLOGY OF
TOMORROW**



**MAKING PROJECTS
HAPPEN**



**SECURED TO BE
DELIVERED**

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- Australia

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