Proven concepts together with new technologies battle the energy crisis

Pumps for renewable power generation

Worldwide, countries have made commitments to significantly increasing their share of electricity generated from renewable sources by 2020. Sulzer Pumps supports fulfilling these targets with tailor-made pumping solutions and services for concentrated solar power generation, geothermal power generation, as well as novel concepts for the storage of electrical energy produced from renewable sources.

Several renewable sources will contribute to meeting the expected demand for clean power. Most scenarios predict notable growth of electricity produced from wind, solar, biomass, and geothermal. Of these, solar power has the highest theoretical potential, as the sun provides the earth with as much energy every hour as human civilization uses every year.

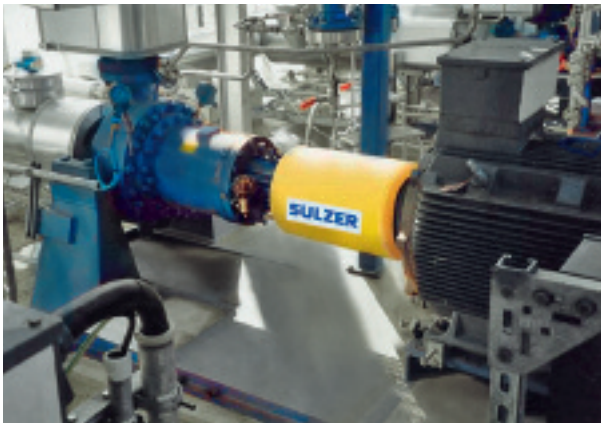
Power from the sun

Converting solar energy into electricity requires a high level of technological expertise. Photovoltaic cells and concentrated solar power (CSP) systems are the most common technologies commercially used for solar-based electricity generation. Photovoltaic panels directly transform sunlight into electricity, whereas CSP systems concentrate sunlight to heat up a working fluid, which is used to operate a steam turbine to produce electricity. This fast-growing type of solar technology requires strong, direct solar radiation and is mostly used in large, centralized installations by utilities.

In CSP plants, pumps are needed to circulate and store the working fluid on the solar island. On the power island, they are used for condensate extraction, feed water, and cooling water circulation.

Solar Thermal Plant Gemasolar, property of Torresol Energy, was the first central tower to be built with molten salts for heat storage of 19.9 MW in Seville, Spain. The plant has storage capacity to produce electricity for 15 hours without sunlight.

1 BBS pumps for heat transfer fluid circulation main.



ZEM/OHM seal-less pumps for heat transfer fluid circulation auxiliary.

Tailored pumps for parabolic trough systems

The most widely used CSP technology is the parabolic trough system, in which long trough-shaped mirrors concentrate sunlight onto thermally efficient receiver tubes located along the trough's focal line. These tubes are filled with a heat transfer fluid, such as thermal oil, which is heated to 285–310 °C. Horizontal single-stage pumps are used to circulate this fluid through heat exchangers to produce superheated steam.

Sulzer manufactures different pump types for this process:

- ZF single-stage process pumps (overhung)
- BBS between bearings single-stage pumps 1, HZB double-suction volute pumps (double flow)

The steam is converted to electrical energy in a conventional steam turbine generator or forms part of a combined steam and gas turbine cycle. The design of the pump's shaft-sealing system is fundamental to assure a reliable operation and to avoid leakages of the hazardous and flammable thermal oil used in this process.

Sulzer Pumps has extensive experience in heat transfer fluid circulation applications since the early 1980's, when the first parabolic trough plants were commissioned in the Mojave Desert in the US.

Highly efficient central-tower systems

The central-receiver technology allows higher temperatures and reaches higher efficiencies than parabolic trough plants. Circular arrays of heliostats concentrate sunlight onto a tower-mounted thermal receiver containing a heat transfer media that converts the solar energy into thermal energy to generate superheated steam. This steam is converted to electrical power through a conventional steam turbine. The heat transfer media can be either water/steam or molten salts. Central-tower systems concentrate heat at higher temperatures compared to other CSP systems, improving their conversion efficiency. The working temperature in such a system is in the range of 500–600 °C, generating supercritical steam and thus optimizing the efficiency of the thermal cycle.

Sulzer Pumps has extensive experience in heat transfer fluid circulation applications.

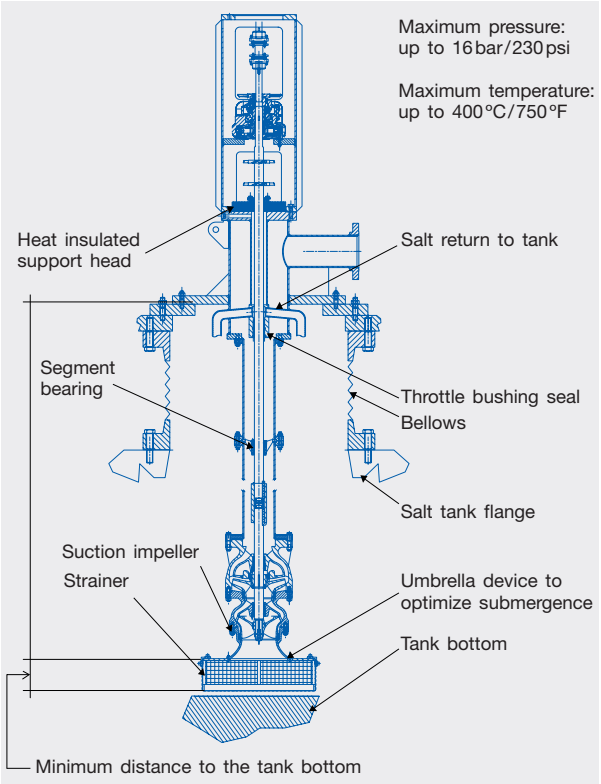
Powering through the night

CSP generates power under direct sunlight, but the heat transfer process with thermal storage integrated into a CSP system ensures power generation during the night or during extended periods with cloud cover. The majority of CSP plants today are supplemented with natural gas fired steam generation. This way a plant can provide base-load power at all times, ensuring a high commercial value to the plant owner. Alternatively, thermal storage technology can allow CSP plants to meet base-load demand without the use of backup fuels. Molten salts are increasingly used today in CSP plants for heat storage or as primary heat transfer fluids due to their high specific heat capacity. When a thermal storage reservoir using molten salts is integrated into a CSP plant, electricity can be generated after sunset, with an extended operation period typically between 6 to 8 hours.

Pumps designed for high-temperature applications

In central-tower units with molten-salt heat storage, the fluids can reach temperatures of up to 570 °C, while in parabolic trough plants with molten-salt storage the temperatures are around 400 °C. The design of pumps for such high-temperature applications requires extensive coordination between materials and plant technology as well as engineering.

Vertical pumps mounted in tanks are preferred nowadays to simplify the molten-salt system. This eliminates the need for pump sumps, isolating valves, level instrumentation, and associated



2 The SJT-VCN molten salt circulation pump for parabolic trough concentrated solar power plants.

heaters. It also reduces heat losses and allows the steam generator system to drain directly into the tanks.

Sulzer's SJT-VCN pump 2 for the circulation of molten salts in a parabolic trough system incorporates the hydraulics from the SJT range. It is a vertical mixed-flow pump with high capacity and medium-to-high head units. It is "engineered to order" and balances high efficiency, low submergence, and NPSH (net positive suction head) considerations.

The SJT-VCN for cold and hot circulation as well as drainage and melting salt applications reach a maximum pressure up to 16 bar and can operate up to a maximum temperature of 400 °C.

Since 1985, Sulzer Pumps has been supplying pumps for central-tower, parabolic trough, linear-Fresnel, and hybrid integrated solar combine cycle (ISCC) applications. To date, Sulzer Pumps has supplied over 450 pumps for more than 25 CSP projects worldwide.

Did you know that…

… if governments around the world carry forward their existing intentions, renewable energy will provide up to half of the new power-generating capacity required between now and 2035?

The table shows the electrical capacity in GW that is required to be installed according to World Energy Outlook 2011 New Policies Scenario. This scenario assumes that recent government policy commitments will be implemented in a cautious manner—even if they are not yet backed up by firm measures.

Electrical capacity (GW)	2009	2015	2020	2035
Hydro	1007	1152	1297	1629
Biomass and waste	53	75	109	244
Wind	159	397	582	1102
Geothermal	11	15	20	41
Solar PV	22	112	184	499
Concentrated solar power	1	7	14	81
Marine	0	0	1	17

What are the sources of renewable power?

Hydropower: The energy is extracted from moving water via a hydroelectric power plant.

Biomass power: The energy stored in organic matter is released directly—in the form of heat or electricity—or converted into liquid biofuel or combustible biogas.

Wind power: The kinetic energy of airflow rotates turbine blades to generate electricity.

Geothermal power: The energy stored in natural reservoirs in the ground is used to generate electricity in steam power plants.

Solar photovoltaic power: Solar cells contain a photovoltaic material and convert solar energy directly into electricity.

Concentrated solar power: Mirrors concentrate the thermal energy of sunrays to produce high-temperature heat for electricity production.

Marine power: Electricity can be generated from the energy in the ocean, using technologies such as tidal power, wave power, ocean-thermal energy conversion, ocean currents, ocean winds, and salinity gradients.

Power from the ground

Geothermal heat originates from the earth's consolidation of dust and gas over 4 billion years. The heat from the earth's core continuously flows outward and conducts to the surrounding layer of rock, the mantle. When temperatures and pressures become high enough, the mantle rock melts becoming magma and moves slowly up toward the earth's crust, carrying the heat from below. Geothermal technologies use the energy stored in rock and in trapped vapors or liquids like water or brine. These resources can be used for generating electricity and providing heat.

Power generation typically relies on geothermal resource temperatures >100 °C. Wells drilled into geothermal reservoirs bring these resources to the surface, generating electricity in geothermal power plants. Several geothermal plant technologies exist today and the total global geothermal installed capacity is ~10.7 GW_e resulting in 67.2 TWh_e produced per year[1].

Sulzer Pumps has been providing pumping solutions for geothermal power generation since 1982.

Extensive portfolio for geothermal plant technologies

Geothermal plant types include dry-steam plants where superheated pressurized steam is brought to the surface at high speeds and passed through a steam turbine to generate electricity. In flash-steam plants, binary-cycle plants, or combined flash/binary-cycle plants 3, the portion of the geothermal fluid which "flashes" to steam under reduced pressure is first converted to electricity with a backpressure steam turbine and the low-pressure steam exiting the backpressure turbine is condensed in a binary system. New technologies like Enhanced Geothermal System (EGS) are under development in Australia and the US.

Sulzer Pumps has been working with customers to provide reliable and cost-efficient pumping solutions since 1982 for geothermal power generation, with an extensive product portfolio and services. The offering includes production pumps such as the SJT Geo, a vertical line-shaft deep well pump up to 650-meter settings specifically designed for geothermal water production applications at shallow field depths. Brine and con-

densate reinjection pumps as well as all pumps for the thermal generating cycle are also in the product portfolio of Sulzer Pumps.

Flexible energy storage

The increasing share of electricity production from unpredictable renewable sources will change the way electrical grids are operated. With the global target of 20 % of renewable power in the electricity mix by 2020, a large share of non-dispatchable and highly intermittent generation will lead to a need for large storage capacity. Several technologies such as compressed-air energy storage (CAES), e-car battery clusters, and electrolysis-producing hydrogen, as well as pumped hydro storage are likely to contribute to meeting these upcoming storage requirements. In a grid with a high share of installed wind and solar power, the power produced may temporarily exceed the current demand, resulting in power being "extracted" from the grid in order to stabilize its frequency. Pumped storage plants move water between reservoirs at different elevations, providing the most efficient means for large-scale grid energy storage. At times of low electrical demand, excess generation capacity is used to pump water into the higher reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine—thus improving the daily capacity factor of the generation system.

New concept for pumped storage

In the early 20th century, Sulzer was among the first companies providing pumped storage equipment worldwide. Building on this experience, Sulzer Pumps has developed a novel concept for pumped storage dedicated to the requirements of the 21st century.

Sulzer provides complete system solutions with state-of-the-art pump technologies for renewable power generation.

Small, decentralized pump storage plants consisting of centrifugal pumps that are used as reverse running pumps will be able to provide a quick response making them an essential component of a mixed power system. These types of storage plants will have an installed power that is lower than conventional pumped storage plants. However, several of such units balancing a larger wind or solar park will ensure optimal use of the renewable power generated. These new pump storage units will make the use of excess renewable power possible without the need to significantly increase grid capacity. This will ensure that the renewable energy, whose power output cannot be controlled by grid operators, will be smooth and dispatchable.

Sulzer supports renewable power

In order to limit the global average temperature increase to 2 °C, the share of electricity from renewable sources will grow significantly in the coming years. Sulzer Pumps is continually developing innovative solutions to ensure a product portfolio to meet the complete pumping requirements for the key technologies that will make this change happen. Pumps from Sulzer operate in concentrated solar power plants, geothermal plants, biomass plants, pumped storage plants, and Sulzer Pumps also has a portfolio for carbon capture storage plants.

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3 Flash/binary-cycle geothermal plant.